Bancroft Area Mines
(Madawaska, Bicroft and Dyno Mines)
Assessment of Impacts on Water,
Sediment and Biota from
Historic Uranium Mining Activities

February 2003

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Ministry of the Environment
Environmental Sciences & Standards Division
Environmental Monitoring & Reporting Branch

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Ⓥ Ontario

Executive Summary

Uranium mining and processing commenced during the 1950's at three sites to the southwest of Bancroft, Ontario: the Faraday Mine (currently known as the Madawaska Mine) at Bow Lake; the Canadian Dyno Mine at Farrel Lake; and the Bicroft Mine at Deer Creek, to the south of Centre Lake. By the mid 1960's all three mines had closed although the Faraday mine reopened as the Madawaska mine in 1976, and operated until 1982. All three mines have been inactive since they shut down. The primary ore minerals in the area were uranothorite and uraninite (Lang *et al*, 1976). As a result of the geochemistry and geomorphology of the area, the tailings generated would be expected to have low acid generating potential and the lakes would have a relatively low acid buffering capacity.

During operation, monitoring of discharge water was carried out at all three mine sites on a regular basis. Monitoring at the sites in the past has indicated elevated levels of contaminants in the surface waters, particularly radium-226 (Ra-226) and uranium at some monitoring sites in Bow Lake in the 1960's as well as downstream of the Bicroft Mine as far as Inlet Bay. No data were reported for Farrel Lake. Data were also collected on a regular basis from the 1960's until 1990 by the Ontario Water Resources Commission and then the MOE through the Provincial Water Quality Monitoring Network. After 1990, samples were collected at only a limited number of stations. These data indicate that at all three mine sites, levels of Ra-226, uranium-238, and gross alpha and beta emitters in the surface waters were elevated above background levels (data from the mid 1980's indicates levels in background lakes were typically at or below detection limits), and that levels occasionally exceeded the Provincial Water Quality Objectives (PWQOs). While most of these exceedances occurred prior to 1990, there is still concern that elevated levels in the sediments may persist adjacent to and downstream of the mine sites.

Although future activities at the mine sites have not been determined, one of the proposed uses put forward by the current owners of the Madawaska and Dyno properties has been to return the sites to Crown ownership. Prior to agreeing to receiving the properties, the Crown needed to determine whether there are environmental liabilities associated with these sites for which the Crown may become responsible. As part of the assessment of potential environmental impacts from these sites, a number of issues related to possible contamination need to be addressed. These include: identification of the contaminants of concern; the potential of the sites to be ongoing sources; the extent and severity of any historical contamination; possible biological effects; and, the long-term implications. The investigation was undertaken as a phased approach, with components of the study not being included until available data indicated that these study components were necessary and would provide useful information (e.g. the collection of fish samples).

Madawaska Mine
Surface water concentrations were elevated above background for both uranium and Ra-226, and uranium exceeded the PWQO at Bow Lake, Bentley Lake and Bentley Creek. Over the last 10 years there has been little or no reduction in metal concentrations discharged to Bow Lake. The data suggests that losses from the site via run-off and leaching, and the remobilisation of metals from the sediment are still ongoing processes.

Levels of uranium and Ra-226 were observed in the surficial sediments at levels 17-times and 405-times (respectively) above background. There are currently no sediment criteria for uranium and Ra-226 in Ontario, however values have been developed for Saskatchewan lakes. These values were adopted for this study. The Saskatchewan uranium Severe Effect Level (SEL) value (390 µg/g) was not exceeded in any of the surficial sediments, though sediments in Bow Lake did exceed this value at depth. Sediment Ra-226 SEL (0.6 Bq/g) were also exceeded at only one location in Bow Lake. Manganese and iron were also elevated in sediments, and exceeded the Provincial Sediment Quality Guideline (PSQG) SEL in Bow and Bentley Lakes (downstream of the mine) for manganese and in Bow Lake for iron. However, both of these metals have low toxicity to organisms. Historical data suggest a continual input of uranium and other metals between the upstream and downstream portions of Bentley Creek, and suggest that the mine tailings may be a source of uranium to the Creek.

Despite elevated levels of metals there seemed to be little effect on the benthic community at any of the downstream sites that could not be associated with possible oxygen stress. The results from the sediment bioassays indicate little toxicity directly associated with the sediments. The bioassay tests also showed that there was uptake of uranium from the sediments by fathead minnows, which could have implications for larger predators and ultimately, human consumers of fish.

Canadian Dyno Mine

Levels of uranium and Ra-226 were much lower in adjacent receiving waters than at the Madawaska Mine site, but were still above background. Surface water concentrations indicated that the compounds of concern downstream of the mine site were iron (which exceeds the PWQO at many of the sample locations), uranium (which at some locations exceeds the interim PWQO of 5 ug/L), and to a lesser extent manganese and strontium (which exceed backgraound at some locations). In comparison to Bow Lake, Farrel Lake showed a similar pattern of metal mobility flux, but with iron as the primary metal rather than manganese.

Field observations indicated that historically, tailings have been deposited in Farrel Lake. Elevated levels of metals (iron, exceeding SEL levels) and radionuclides (Ra-226 exceeding the SEL level for Saskatchewan lakes) were observed in the surface sediments. The elevated levels of uranium (and also lead, which both exceed the SEL immediately downstream of the tailings area) in the sediments from the beaver pond, adjacent to Farrel Lake, suggested that some of the metals have been transported out of Farrel Lake. The relatively high surface concentrations of uranium in the pond sediments suggest input from external sources, such as Farrel Lake, is an ongoing process.

Despite the presence of tailings at the north end of Farrel Lake and the elevated levels of metals in the sediments, there was no apparent effect on the benthic community; the primary impact on the community was felt to be due to low oxygen concentrations. Sediments at one location below the Dyno Mine site (DM-3) showed a significant increase in mortality. However, it was felt that the toxic results were not due to uranium levels in the sediment and were considered a result of high organic material at this location.

Bicroft Mine

Concentrations of some metals (e.g. iron, manganese, cobalt and uranium) were elevated above background at locations below the Bicroft Mine site (particularly in a small tributary that drains the

site, as well as Deer Creek), however, concentrations in the first receiving body of water (Inlet Bay of Paudash Lake) were generally low. Uranium levels below the site were above background and occasionally exceeded the interim PWQO of 5ug/L. The sampling program also identified the site as a source of Ra-226 to the system, although concentrations did not exceed the PWQO of 1Bq/L. Overall the concentrations of metals in the receiving waters were lower than the other sites.

Background concentrations in the sediments of most metals were lower in Centre Lake than either of the other two background locations (Bentley and Brough Lakes). Sediment uranium levels were slightly elevated from background, and Ra-226 and manganese exceeded the SELs at an area adjacent to the tailings dam. The presence of higher concentrations in the sediments suggests that there has been some movement from the tailings areas to Centre Lake. While sediments below the Pond A discharge (BM-4) were elevated in uranium, Ra-226 and manganese, the most significant increases in uranium concentrations were observed at the mouth of Deer Creek at Inlet Bay and in Inlet Bay itself. Concentrations of uranium and Ra-226 in the surficial sediments of the lower portion of Paudash Lake are higher than background, and are also higher that subsurface sediments, and suggest a relatively recent dispersal of uranium and Ra-226.

The lack of biological effects below the site that could be due to toxicity of metals is related to the availability of metals from sediment. The lack of a pronounced toxic effect suggests that the availability of metals from the tailings is relatively low. Discharge from the site appears to have only a minor effect on the downstream benthic community. The elevated levels of some metals in the sediments of Inlet Bay may also be having an effect on the benthic community, however, the community was dominated by a high abundance of species tolerant to low oxygen conditions suggesting that the primary factor effecting the benthos is periods of low oxygen in the bottom waters. Results from the sediment bioassay tests showed an increase in mortality only in the mayfly test from the sediments from Deer Creek. The tests also found that uptake of uranium from sediments at the mouth of Deer Creek by fathead minnows occurred at a higher rate than any other sediment tested, and may have implications for larger predators.

Based on the findings from this study, recommendations have been made to:

i)   Identify and control discharges to the surface water (including tailings area, mine seepage, etc) of metal such as iron, manganese, uranium and Ra-226 from the Madawaska Mine and Canadian Dyno Mine sites.
ii)   Continue routine monitoring of tailings effluent discharge at all of the mine sites.
iii)   Undertake fish sampling from the receiving lakes of all three mines, and analysis for radionuclides to ensure there are no human health concerns regarding the consumption of these fish.
iv)   Continue monitoring of the water column downstream of all three mine sites.
v)   Sediment remediation does not appear to be necessary at any of the mine sites, however this recommendation may need to be re-evaluated should the sport fish tissue residues indicate elevated levels. The sediment should also be re-assessed in 5 to 10 years, to determine if improvements have occurred as a result of source control efforts.

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1.0 Introduction

In the 1950's uranium mining and processing commenced at three sites southwest of Bancroft (Figure 1): the Faraday Mine (currently known as the Madawaska Mine) at Bow Lake; the Bicroft Mine at Deer Creek, south of Centre Lake; and the Canadian Dyno Mine at Farrel Lake. By the mid 1960's, all three sites had closed, though the Faraday Mine was reopened in 1976 as the Madawaska Mine. The Madawaska Mine operated until 1982, when it was again closed. The three sites have been inactive since they were shut down. Lang *et al* (1976) note that the primary ore minerals in the area were uranothorite and uraninite (UO_2). They go on to note that the Faraday Mine was located in a zone of pegmatitic granite dykes containing uranothorite and uraninite with minor uranophane and that the ore averaged 0.1 per cent U_3O_8. Lang *et al* (1976) note that the area is typically granites and gneisses. As such, the tailings generated would be expected to have low acid generating potential, though it should be noted that the local geology also indicates these lakes would have relatively low acid buffering capacity.

Monitoring at the sites in the past has indicated that there are concerns regarding the levels of radioactive elements in surface waters, and their potential for ecological health effects. During operation, monitoring of discharge water was carried out at all three sites on a regular basis, and a summary of the monitoring data are presented in *Report on Radiological Water Pollution in the Elliot Lake and Bancroft Areas*. (Deputy Ministers' Committee, 1965). The report notes that elevated levels of radium 226 (^{226}Ra) were found at some monitoring sites in Bow Lake in the 1960's. The same study noted elevated levels of radium-226 downstream of the Bicroft Mine as far as Inlet Bay of Paudash Lake. No data were reported in this study for Farrel Lake.

Beginning in the late 1960's the Ontario Water Resources Commission undertook periodic sampling of the surface water at these sites for radium-226 and gross alpha and gross beta emitters. In the 1970's, the Provincial Water Quality Monitoring Network was established, and data collection continued at a number of sites upstream and downstream of each of these mine sites. Provincial water quality monitoring stations were located downstream of the discharge points at each of the mine sites. Water quality was monitored at these sites for a large number of parameters from 1964 to 1999. Sampling continued on a regular basis until 1990, after which a number of the monitoring sites were dropped from the program. As a result, samples were collected at only a limited number of stations.

In addition, during the mine operating span, surface water quality monitoring was undertaken on a periodic basis by the property owners. Sampling was undertaken at the Madawaska Mines site in accordance with AECB requirements, and included water sampling and on one occasion, sampling of fish tissues (Beak 1988). The latter study concluded that there was no threat to human health from consumption of sport fish.

A review of the available data from the Provincial Water Quality Monitoring Network (PWQMN) (Table 1) indicates that at all three mine sites, levels of Ra-226, U-238 and gross alpha and beta emitters in surface water were elevated above background levels (data from the mid 1980's indicates levels in background lakes were typically at or below detection limits), and that levels frequently exceeded Provincial Water Quality Objectives (PWQOs).

While the PWQMN data indicate that most of the PWQO exceedances for the compounds of concern occurred prior to 1990, there is concern that elevated levels in sediments may persist adjacent to and downstream of the sites.

A study by Beak Consultants for the AECB (Beak 1998) using spiked sediment bioassays found that concentrations in sediment in excess of 40 µg/g dry weight of uranium resulted in 50% mortality in juvenile amphipods (*Hyalella azteca*), while concentrations in excess of 284 µg/g resulted in similar mortality among adult amphipods.

Other studies conducted by the AECB (Kurias *et al*, 2000) in northern Saskatchewan derived site-specific screening level concentrations that would be expected to adversely affect 95% of benthic invertebrate species, which they termed "SELs", for uranium (390 µg/g) and Ra-226 (0.6 Bq/g). 'No effect levels' were not derived in this study.

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1.1 Madawaska Mine

The Madawaska Mine is located beside Bentley Creek between Bentley Lake and Bow Lake (Figures 2 and 3), and began operation as a uranium processing facility in 1957 as the Faraday Uranium Mine Ltd. The original Faraday Mine closed in 1964 but the mine was re-activated in 1967. In 1976 the mill was put back into operation under the current name and was operated until 1982, when it was again closed. In 1983, the AECB issued Decommissioning Approval AECB-DA-139-0 for decommissioning of the site (Beak 1988). As of 2000, all buildings on the site have been removed, though the foundations still exist in some cases.

Madawaska Mine Site: View from tailings disposal site east towards Bentley Lake
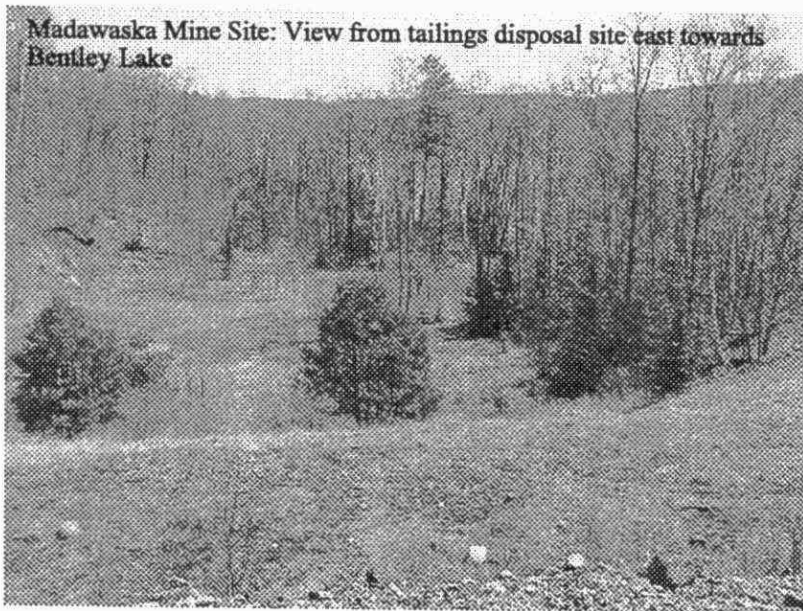
Lang *et al* 1976, note that ore from the Greyhawk Mine, located south of the Madawaska (Faraday) Mine, was shipped to the Faraday plant from 1957 to 1959.

As early as 1957, there were reported complaints from residents regarding water quality at the east end of Bow Lake (Deputy Ministers Committee, 1965). By 1960, problems with increased radioactivity in water of Bow Lake became apparent. Analysis of Bow Lake water showed elevated gross alpha counts that were 10 times maximum permissible limits. Additional sampling in 1962 indicated there were still problems of radioactive materials leaking into Bow Lake (Deputy Minister's Committee, 1965).

In addition to PWQMN sampling from 1966 to 1996, limited sediment and biological sampling was undertaken at Madawaska Mines site (Bow Lake). In 1988, Beak Consultants undertook a study in Bow Lake to determine the potential human health effects of consuming sport fish due to the presence of radionuclides in fish tissue.

In the late1980's the MOE's Eastern Region also undertook studies on Bentley Lake. Sampling determined that the lake was meromictic, and the mine runoff/drainage was identified as a likely cause (D. Galloway, Pers. Comm. 2000).

1.2 Bicroft Mine

The Bicroft Uranium Mines Ltd. site is located along Deer Creek, below Centre Lake (Figures 4 and 6). Mining commenced at this site in 1956 and the mine closed in 1963. Tailings from the operation were discharged mainly to Auger Lake, which is separated from the lower basin of Centre Lake by a tailings dam adjacent to Hwy 121. Auger Lake was originally a wetland area that was dammed at the north and south ends to create a tailings disposal pond. A reproduction of a rough map of the area from 1965 (Deputy Minister's Committee, 1965) is included as Figure 7. The map shows a small creek from the north end of the tailings area to Centre Lake, while currently the edge of the tailings disposal area abuts Hwy 121. Therefore, the tailings disposal area was smaller than exists currently (likely through rising water levels).

Auger Lake drains through a weir and spillway to a small creek which flows south to a beaver pond known as "pond A". In addition to trapping any tailings from Auger Lake, this beaver pond also receives drainage from a second tailings disposal area to the south of the pond. Below the beaver pond, the creek flows approx. 500 m southeast and then joins

Deer Creek approx. 0.5 km upstream of Paudash Lake (Inlet Bay at the northeast end of the lake). A study undertaken in 1965 (Deputy Minister's Committee), notes that a tailings breakout occurred to Inlet Bay of Paudash Lake in 1957.

In 1986 and 1987, MOE undertook a study at the Bicroft Mine site. As part of this investigation by MOE Central Region, water samples, sediment samples and fish tissues were analyzed for radionuclides.
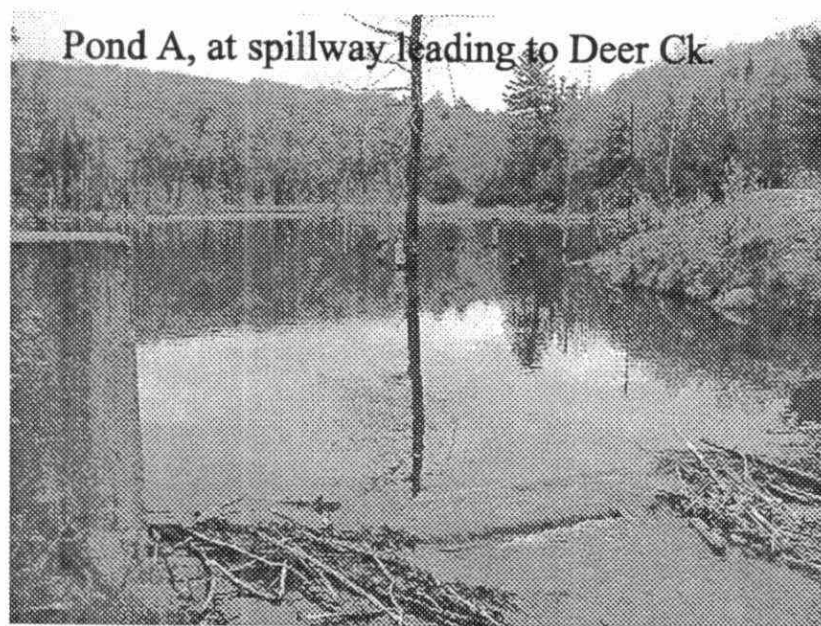
Pond A, at spillway leading to Deer Ck.

Sediment samples collected from Deer Creek, below the mine site showed levels of uranium up to 690 µg/g as compared to 9 µg/g from Baptiste Lake (used as a background in that study).The levels in Deer Creek would also be above the levels, in studies conducted for the AECB, that would be expected to have adverse effects on sediment-dwelling organisms. Levels in Inlet Bay (Paudash Lake) ranged up to 120 µg/g, while sediments in North Bay of Paudash Lake were 67 µg/g. The data suggest that sediment contamination by elemental uranium extends for a considerable distance from the mine site. It is anticipated that similar dispersion of sediment-bound metals and radionuclides has occurred at the other mine sites as well.

In addition to uranium, sediment concentrations of radium-226 were also measured. Levels in Inlet Bay (Paudash Lake) yielded the highest levels at 27 Bq/g, as compared to 0.04 Bq/g in Baptiste Lake. As such, levels in Inlet Bay sediments were 675 times the levels in background lake sediments. Sediment studies conducted by the AECB in northern Saskatchewan (Kurias *et al* 2000) derived a site-specific "SEL" for radium-226 of 0.6 Bq/g.

In the studies conducted by the MOE in 1986 and 1987, fish collected from Inlet Bay also had elevated levels of radium-226 as compared to levels in fish from Baptiste Lake. Yellow perch from Inlet Bay had radium-226 levels of 12 mBq/g of flesh, compared to 0.25 mBq/g of flesh in fish from Baptiste Lake. Data for small mouth bass were similar, with 17 mBq/g of flesh for fish from Inlet Bay and less than detection limit (0.19 mBq/g) in fish from Baptiste Lake. Only white suckers had detectable tissue residues of uranium (0.15 µg/g flesh) (levels in Baptiste Lake were below the detection limit of 0.05 µg/g).

1.3   Canadian Dyno Mine

The Canadian Dyno Mines Ltd. mine site began operation in 1957, and closed only three years later, in 1960. The mine site (including tailings area) is located at the north end of Farrel Lake (Figures 4 and 5). Farrel Lake in turn drains to the northeast end of Eels Lake via Farrel Creek. Tailings were discharged to a dammed section of a small creek at the north end of Farrel Lake. Currently, the tailings area is held behind this tailings dam. A map included in the 1965 report by the Deputy Minister's Committee shows Farrel Lake extending further north than more recent maps. It appears that the tailings dam was constructed across the northern arm of the lake, with tailings disposed of behind this dam (Figure 8). Currently, the north shore of Farrel Lake, adjacent to the tailings dam, is a wetland area. Visible staining of soils and sediments is evident in this area. In addition, the lake bottom adjacent to the wetland is covered with tailings.

The eastern end of the tailings dam has been excavated as part of an engineered spill way, to ensure dam integrity, and

Dyno Mine - Tailings dam at north end of Farrel Lake
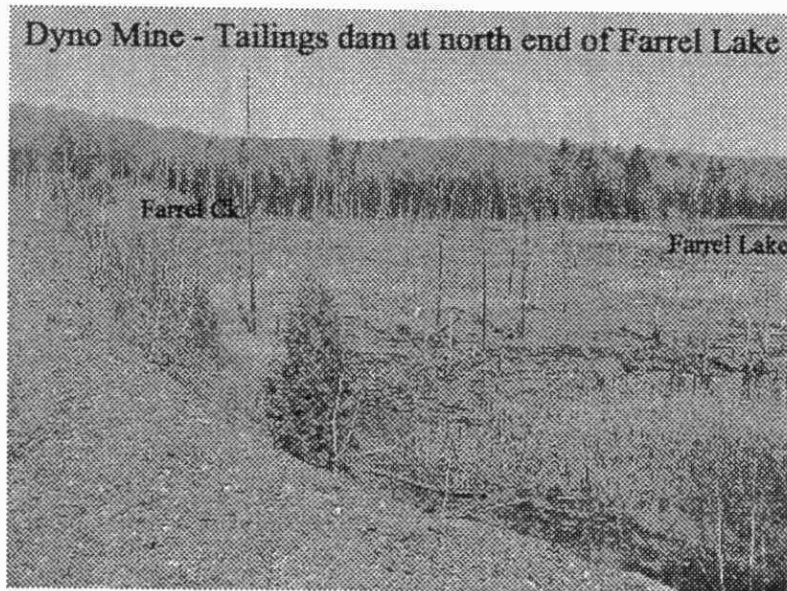
permits unimpeded flow of the creek into Farrel Lake. As such, there currently seems to be no sediment/erosion control on this creek to control movement of mine tailings.

PWQMN data from 1966 to 1989 show levels of arsenic and iron, in addition to radionuclides, that are elevated above background, and suggest that sediments adjacent to, and downstream of the mine and tailings areas could also be contaminated. It is anticipated that sediment concentrations of radium-226 would be similar to levels recorded in the MOE 1986 survey of the Bicroft Mine site.

1.4   Purpose of Study

Issues exist regarding possible water and sediment contamination at the three mining sites. The limited amount of sampling conducted in the past suggests there may be on-going concerns in some areas, (for example, sediment contamination), that have not been investigated in the past. Future activities at the mine sites have not been determined, but as part of evaluating the potential uses for these sites, the impacts of past uses need to be determined.

One of the proposed uses, put forward by the current owners of the three properties has been to return the sites to Crown ownership. Prior to agreeing to receiving the properties, the Crown needs to determine whether there are environmental liabilities associated with these sites for which the Crown may become responsible. Even if the properties are not returned to Crown ownership, the current environmental conditions at the sites, aside from water quality, are largely unknown and should be determined before any future uses are considered.

As part of the assessment of potential environmental impacts from these sites, a number of questions related to possible contamination needed to be addressed.

1.   What are the contaminants of concern? Previous studies have identified a number of radioactive elements that are of potential concern. Are there additional elements that may have been released during the processing of the ore that could also be of concern?

2.   Are the sites, or any part of the sites, continuing to act as a source of any contaminants to the adjacent aquatic environment?

3.   What is the extent and severity of any historical contamination from these sites on both water column and sediments? Is there a possibility that sediments are contaminated and could continue to act as a source in the future?

4.   Are there any biological effects associated with elevated levels, if any, of contaminants in the water column or sediments? How severe are these effects? What is (are) the source(s)?

5.   Are there any long-term implications from contaminants at any of these sites? This could include a range of

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possible actions that may be required on the part of any potential new owner (i.e., the Crown). These actions may range from periodic environmental monitoring to full-scale sediment remediation.

6.   Recommended actions that should be undertaken before the Crown accepts title and hence responsibility for these sites.

2.0   Methods

The site investigation was undertaken as a phased approach. The intent was not to include components until available data indicated that these study components were necessary and would provide useful information.

All three sites were considered as one project and the investigation of all three sites was conducted concurrently. The Madawaska Mine site at Bentley Lake/Bow Lake, and the Bicroft Mine at Centre Lake, both ultimately drain to the Crowe River system, and thus warranted investigation together. The Dyno Mine site at Farrel Lake drains south to Eels Lake and through Eels Creek to Stoney Lake.

Since relatively little data existed on all three mine sites, the initial step in the investigation of each site was comprised of sediment and water quality data collection. Sampling locations were based on expected dispersion and transport of contaminants and endeavoured to include all potentially impacted areas downstream. Sediment and water samples were collected concurrently, beginning in May 2000. Subsequent collection of water samples, and a limited number of sediment bioassay samples was undertaken in August. Additional water sampling was undertaken again in November. The sampling locations are shown on Figures 2 through 6. The intent of this component was to quantify current contaminant levels in water and sediment immediately adjacent to, as well as downstream of each site and, in the case of water samples, to document any seasonal changes in contaminant distribution. For each of the three mine sites, local background lake and stream sites were selected for sampling. These were selected so as to be within the same watershed, and thus within the same geological area, but upstream of the influence of any of the mine activities.

Water samples were collected at the surface from all sites. Samples were collected into 500mL plastic containers for analysis of nutrients, salts, and metals, including uranium. In addition, at each site, an additional 2L were collected for analysis of radionuclides by the AECB laboratory in Ottawa. At certain locations conductivity profiles were taken down through the water column. Readings were collected every 0.5 meters from the surface to the bottom with a conductivity meter. At those locations where a significant increase in conductivity was noted at the bottom, additional water samples were collected for both metals/nutrients/salts and radionuclides at approx. 1 m off the bottom. Bottom water samples were collected with a Van Dorn water sampler. Samples were collected directly into the appropriate sample containers. Samples for metals and radionculide analysis were preserved in the field with nitric acid.

Sediment samples were collected with either a benthos gravity corer (in shallow areas such as streams) with a plexiglass tube of 4" diam., or a K-B Corer with a plexiglass tube of 2" diam. At each location, three replicates (benthos gravity corer) or five replicates (K-B corer) were collected. The core was divided into three sections: 0-10 cm; 10-20 cm, and; 20-30 cm. The corresponding sections from each of the replicates were combined, the sample was homogenized, and a subsample of the homogenate collected into 500mL plastic sample bottles. Two sample bottles were collected for each sediment sample: one sample was for submission to the MOE laboratory Toronto, Ontario for nutrient and metals (including uranium) analysis (using Aqua Regia extraction), while the second sample was submitted to the Ministry of Labour (MOL) Radiation Protection Laboratory, Toronto, Ontario for analysis of a suite of radionuclides, including radium-226 and uranium-238.

Water and sediment samples were analyzed for a suite of metals, including arsenic, copper, iron, manganese, strontium and uranium. Radionuclide analysis was also conducted for uranium, while strontium was only analyzed as total

elemental strontium.

Concurrent with sediment and water sample collection, benthic community samples were also collected at each of the sampling sites. Samples were collected with a stainless steel Ekman sampler of 12" x12". Three replicates were collected at each location. Each replicate was washed in the field using a standard U.S.#30 mesh sieve to remove fine particles, and the sample residues were preserved separately in 10% formalin neutralized with sodium borate. Samples were submitted to Zaranko Environmental Assessment Services (ZEAS) for sorting and detailed analysis. All three replicates were sorted, and the organisms removed were identified to order and enumerated. The replicate that came closest to the mean was subsequently chosen for detailed analysis of the organisms present. Since sampling locations were chosen on the basis of anticipated dispersion of contaminants, the sample locations included both lakes and river habitats. Consequently, it was not possible to ensure similar habitats were sampled at all locations and resulted in a range of habitats, from deep lake basins, to shallow depositional zones along the margins of rivers.

Based on the results of the initial sediment sampling, 10 locations were chosen for laboratory sediment bioassay testing. Samples were collected during August 2000, at the same time as the second set of water samples was collected. Samples were collected with a stainless steel Ekman sampler. Details of the test protocol are provided in the next section.

2.1   *Laboratory Sediment Bioassay Tests*

This report provides the results and interpretation of whole-sediment toxicity tests conducted by OMOE, Standards Development Branch (SDB) following documented sediment toxicity test methods (Bedard *et al.*, 1992). The standardized laboratory tests were completed for ten samples using the mayfly nymph, *Hexagenia limbata* (22-day exposure, survival, growth and avoidance), the midge larvae, *Chironomus tentans* (10-day exposure, survival and growth) and the juvenile fathead minnow, *Pimephales promelas* (21-day exposure, survival and chemical bioaccumulation). The battery of sediment toxicity tests provides several endpoints using organisms representing different trophic levels in order to measure differences in sediment quality. The laboratory toxicity tests are a cost-effective technique for determining whether sediment-associated contaminants are harmful to benthic organisms or are being released into the water column.

In conjunction with appropriate negative and reference sediments, spatial differences in sediment quality, the relative availability of contaminants and their potential impacts can be ascertained. Sediment contaminant concentrations were based on samples prepared for laboratory toxicity testing. The sediment was analyzed for particle size, nutrients, metals, and a suite of organic compounds, including PCBs. Surviving fathead minnows were submitted for whole-body tissue analysis of uranium.

Sediments for laboratory bioassay testing were collected in August at nine experimental locations and one reference location (locations of sampling sites are shown on Figures 2 through 6). Selection of sample sites was based on known or expected sediment contamination within the study area. Samples were collected using an Ekman grab sampler. At each station, approximately 10 L of composited surficial sediment (top 10 cm) was collected from several grabs. (Exact depth may have varied depending on sediment type and ease of collection). The composited sediment was placed into 20 L plastic pails lined with food-grade polyethylene bags and transported to the MOE Toronto, Ontario laboratory and stored at 4°C until required.

The reference control sediment was situated at an upstream location to reflect background contaminant levels within the region. As such, the reference sediment helps to measure what influence sediment type and naturally occurring contaminant levels can have on the biological test endpoints. Sediment collected from Honey Harbour, Georgian Bay, Ontario served as the negative control sediment. The negative control sediment is a relatively uncontaminated sediment that provides a measure of test acceptability. Both the negative and reference control sediments also provide a basis for comparing the biological responses from the test sediments (ASTM, 1997a).

Chemical analysis of sediment and biota samples was conducted by the OMOE, Laboratory Services Branch, located in Toronto. Test methods are described in the *OMOE Handbook of Analytical Methods for Environmental Samples* (OMOE, 1993). Quality assurance procedures included method blanks, spikes, duplicates and standard reference materials. Samples were analyzed for total phosphorus, total Kjeldahl nitrogen, total organic carbon and percent loss on

ignition. Metals analysis included As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn, and U.

2.1.1 Laboratory Biological Testing Methods

Basic Experimental Design

Sediment biological tests were conducted according to OMOE standardized procedures (Bedard *et al.*, 1992) and are briefly described below. The bioassays were static, single-species tests using whole-sediment. The experimental unit was a 1.8 L test chamber containing prepared sediment and dechlorinated municipal tap water (1:4, v:v). The chambers were randomly placed into a holding tank at ambient room temperature and maintained under a 16:8 hour, light:dark photoperiod and continuous aeration.

Moist field-collected bottom sediment was passed through a 2-mm stainless-steel sieve to remove existing large biota and debris prior to use. Subsamples of this homogenized sediment were submitted for chemical and physical characterization according to standard OMOE procedures (OMOE, 1993). The sieved sediment was homogenized with a spatula and stored in 4 L acid-rinsed glass jars until required. Three hundred and twenty-five millilitre aliquots of homogenized sediment were placed into the test chamber and overlaid with the test water. After settling overnight, the chambers were aerated continuously until the end of the test. A clean, negative control sediment was collected from Honey Harbour, Georgian Bay. Negative control mortality must not exceed 15% for mayflies and fathead minnows and 25% for chironomids or the test is declared invalid.

Water in the exposure chambers was regularly monitored for pH, conductivity, total ammonia, un-ionized ammonia and dissolved oxygen. Dead organisms were removed and the numbers recorded daily in the mayfly and minnow tests. Any signs of abnormal behaviour of the test organisms or changes in appearance of the test chambers were noted. Water loss due to evaporation was replenished as needed.

Hexagenia limbata Lethality and Growth Assay

The toxicity test used six month old laboratory-reared mayfly nymphs with an average wet weight of 6.82 mg ± 0.37 (s.e.) (n=38). The nymphs were raised from eggs collected by Dr. J. Ciborowski at the University of Windsor, Windsor, Ontario. Mayflies were reared according to OMOE procedures (Bedard *et al.*, 1992) and methods described in the literature (Friesen, 1981).

The rearing procedure involved the transfer of 600 newly-hatched nymphs to a 6.5 L aquarium which contained 2 cm of autoclaved sediment and 5.6 L dechlorinated tap water. Animals were maintained at ambient room temperature, 16:8 hour, light:dark photoperiod, continuous aeration and fed a vegetable diet.

Test organisms were retrieved from the rearing aquaria by sieving small portions of sediment in a 500-μm mesh brass sieve. The nymphs were washed into an enamel tray which held a fine mesh sieve and aerated, dechlorinated water. A Pasteur pipette (5-mm opening) was used to transfer the mayflies into 100 mL beakers of water and the contents were gently poured into the test chambers. Each test involved adding ten nymphs to each of the three replicate test chambers for a period of 22 days. The test duration slightly deviated from the standard 21-day test period but is not expected to contribute significantly to the final test outcome. Animals were not fed during the length of the test.

At the end of the test, the contents of each test chamber were emptied and rinsed in a sieve bucket. Surviving animals were counted and transferred to 150 mL beakers holding 100 mL dechlorinated water. The nymphs were immobilized with Alka-Seltzer®, blotted dry and individuals weighed to the nearest 0.01 mg.

Chironomus tentans Lethality and Growth Assay

Each toxicity test used 10-12 day old, cultured chironomid larvae weighing an average wet weight of less than 1 mg. The OMOE maintains continuous cultures of *C. tentans* larvae from egg to adult, following standard methods (Bedard

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et al., 1992, Mosher *et al.*, 1982, Townsend *et al.*, 1981). Egg masses were originally supplied by Dr. J. Giesy at Michigan State University, Lansing, Michigan and have been cultured for several generations in our laboratory.

Initially, the midges were reared in enamel trays for 10 to 12 days and then maintained in a 21 L aquarium containing 1.6 L of silica sand. The cultures were held at ambient room temperature with continuous aeration and under a 16:8 hour, light:dark photoperiod. The larvae were provided a vegetable diet *ad libitum*.

Second and third instar larvae were directly transferred from the enamel rearing trays into the test chamber using the 5-mm opening of a Pasteur pipette. A total of 15 animals were added per chamber to each of the three replicates. Animals were fed daily 30 mg of a Cerophyll®:Tetra Spirulina® (3:2, w:w) diet.

After 10 days, the contents of the test chambers were emptied and washed in a sieve bucket. Surviving animals were sorted, removed and placed into 150 mL beakers holding 100 mL dechlorinated water and 15 mL silica sand. The larvae were counted, blotted dry and individuals weighed to the nearest 0.01 mg.

Pimephales promelas Lethality and Bioaccumulation Assay

The tests used cultured, juvenile fathead minnows with an average wet weight of 276 mg ± 15 (s.e.) (n=30). The minnows were cultured at the OMOE laboratory following techniques which for the most part are US EPA procedures (USEPA, 1987) with minor revisions (Bedard *et al.*, 1992).

Cultures were maintained at 20°C in a flow-through dechlorinated water system and under a 16:8 hour, light:dark photoperiod. Breeders were kept in 60 L glass aquaria and eggs were laid on spawning tiles. The tiles were incubated in a 25°C water-bath and the developing larvae were transferred to 400 L fibreglass holding tanks. Larval fish were fed 48-hour old live brine shrimp while juveniles and breeders were provided frozen brine shrimp. Each size class was fed *ad libitum*.

Each test chamber received ten juvenile minnows for each of the three replicates. The minnows were sorted into 250 mL glass beakers in groups of five. The contents of the beakers were emptied into a small net and the minnows released into the test chamber.

The minnows were exposed for 21 days and fed a NutraFin Staple® diet daily in an amount equivalent to 1% of the average starting wet weight. After 21 days the surviving fathead minnows were pooled from each replicate, counted, immobilized with Alka-Seltzer®, rinsed thoroughly with distilled water and placed into 30 mL glass vials and frozen pending chemical analysis.

Each bioassay complied with the recommended maximum storage period for sediment samples designated for toxicity testing of six weeks (EC, 1994).

2.1.2   Statistical Methods

Statistical analyses were performed using the SAS® software package (SAS, 1985). Comparisons were made among the test and control sediments using One-Way Analysis of Variance (ANOVA) and Tukey's studentized range test (HSD) and planned comparisons (Steel and Torrie, 1960). Dunnett's one-tailed *t*-test was used solely to compare mortality between the control and test sediments and the associated minimum significant difference (MSD) was described as a measure of test sensitivity. Analysis was made on arc-sine transformed mortality data. Homogeneity of variance across groups was tested using Bartlett's test and Shapiro-Wilks test for normality. Coefficients of variation were calculated for each endpoint as a measure of test precision. Spearman rank correlation analysis was used to investigate the correlation among the different biological endpoints for each species and sediment characteristics. Differences in whole-body tissue residues for metals among sites was determined using Tukey's studentized range test on homogeneous data and Kruskal-Wallis rank test on non-homogeneous data. Statistical analysis was carried out on log-transformed tissue data. Correlation analysis was used to measure the strength of the relationship between tissue and sediment chemical concentrations. All

contaminant tissue residues were converted to a dry weight basis using a dry weight ratio of 0.15.

3.0 Results

3.1 Water Quality Analysis

3.1.1 Field Measurements

Only conductivity measurements were taken at all stations in the field (Table 3). During the summer and fall sampling, temperature was also recorded at the sampling sites. At a number of the lake stations, conductivity measurements were taken at 0.5m intervals through the depth of the water column. The results are shown on Figures 9 and 10.

Data gathered from the background lakes (MM-LC, DM-LC, BM-LC) indicates that conductivity remained the same throughout the vertical extent of the water column, even during the summer sampling period when a definite thermocline existed in these lakes. However, in those lakes adjacent to the mine sites, namely Bentley Lake and Bow Lake (Madawaska Mine) and Farrel Lake (Dyno Mine), conductivity of the bottom water was considerably higher (up to 5-times) than at the surface. This is shown graphically in Figure 10. During the fall, after turnover of these lakes, only Bow Lake (station MM-5) still showed a difference in surface vs. bottom conductivity. The other lake stations sampled showed little change between surface conductivity and bottom water conductivity, indicating that complete mixing of the water column had occurred during fall turnover. The deep eastern basin of Bow Lake is in part protected by a sill to the west (near the island/peninsula), that would also partially restrict water movement in this area. However, the high concentrations of some metals (e.g., manganese, see Section 3.2) have likely contributed to the formation of a distinct density gradient that appears to persist year round.

3.1.2 Nutrients and Metals

Results of chemical analysis of water samples are presented in Table 3. The data show that only a few of the parameters tested had elevated levels at stations below the mine sites. At all three mine sites, levels of uranium, iron, manganese, aluminum and strontium increased below the sites. In the lake stations, levels of metals were typically much higher near the bottom than at the surface. The concentrations of metals found in the surface waters are shown graphically on Figures 11 through 14.

Madawaska Mine:
Concentrations of metals in Siddon Lake (station MM-LC) are considered as representative of this area and thus form the local background levels. Water concentrations of aluminum, cobalt, iron, manganese, strontium and uranium all increased over background in Bentley Lake (Figures 11 through 14). While levels of manganese and strontium were higher in bottom water at the north end of the lake (station MM-1), levels of uranium, iron, cobalt and aluminum were higher at station MM-2, located near the south end, adjacent to the grout curtain (Table 3). Manganese levels in bottom water at station MM-1 in May increased from 44 µg/L at the surface to 1430 µg/L at the bottom, a 33-fold increase (and 170 times background levels), while iron increase by a factor of 7 (from 52 µg/L to 381 µg/L). Aluminum increased from 8.7 µg/L to 27.9 µg/L (a 3-fold increase), strontium increased from 727 µg/L to 2040 µg/L, (also a 3-fold increase) and uranium increased from 12.7 µg/L to 41.1 µg/L (a 3-fold increase). The data suggest that the significant increase in conductivity noted near the bottom during the field profiling is most likely attributable to the increases in manganese and iron, and to a lesser degree to the presence of aluminum, cobalt, strontium and uranium. In the August sampling, levels of uranium in the bottom water were slightly lower (35.1 µg/L) than in May, though levels at the surface were also lower, resulting in a more pronounced difference (5-fold) than during the May sampling. However, both manganese and strontium increased in bottom water samples in August, with manganese showing the largest change (from 14 µg/L to

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2100 µg/L or a 150-fold increase), while strontium increased only from 2040 to 2330 µg/L (a 5-fold increase over surface water concentrations). Sampling in November revealed that the conductivity difference between surface water and bottom water at station MM-1 had disappeared, but the overall conductivity of the surface water was much higher (505 uS/cm at station MM-1 and 506 uS/cm at station MM-2) than during the spring (366 to 369 uS/cm) or summer (277 to 281 uS/cm). Results from November also show a reduction in concentrations of most metals in bottom water at station MM-1, such that concentrations were similar in both surface and bottom water samples.

At station MM-2, a larger increase in Al was noted than at station MM-1. Similarly, the increase in uranium concentrations at the bottom was slightly larger than at station MM-1 (from 7.35 µg/L at the surface to 68.4 µg/L at the bottom, or an increase of 9-times). Manganese concentrations in bottom water showed marked seasonal changes and were substantially higher in August (2130 µg/L) than in May (689 µg/L). Nevertheless, concentrations were very similar to concentrations at station MM-1. Iron concentrations in bottom water however were higher at station MM-2 (381 µg/L) in May than at station MM-1(466 µg/L), but the difference was even more marked in August when concentrations at MM-1 dropped to 174 µg/L but levels at MM-2 rose to 833 µg/L. Strontium levels also increased at stations MM-2 over levels at MM-1. During May bottom water concentrations were very similar at both stations (2040 µg/L at station MM-1 vs 1930 µg/L at MM-2), but levels at station MM-2 rose to 3340 µg/L, while concentrations at MM-1 remained approximately the same (2330 µg/L). As noted for some of the other metals, such as manganese and iron, surface concentrations of strontium decreased at both these stations in August, while bottom water concentrations increased, resulting in a much greater differential. As a result, the difference between surface and bottom water concentrations in August rose to 7-fold from a previous 3-fold difference. While concentrations of uranium, strontium and manganese at station MM-1 were similar in both surface and bottom samples during the November sampling, the results from MM-2 showed significantly higher bottom water concentrations than surface concentrations. Levels of these metals decreased from the highs recorded during the August sampling only to concentrations similar to the samples collected in May. Unlike station MM-1, a conductivity difference persisted into the November sampling period at station MM-2. While surface conductivity had increased to 506 uS/cm, likely due to mixing of bottom water during the lake fall turnover, conductivity in the bottom water sample was still elevated, at 823 uS/cm than the surface water.

Concentrations of most parameters at stations MM-3 and MM-4, both located in the creek adjacent to the mine tailings areas, were similar to the surficial concentrations in Bentley Lake. While uranium concentrations at both stations were similar in the May and August sampling, concentrations increased at station MM-4 in November (the other metals showed a decrease in November from MM-3 down to MM-4). The higher conductivity readings at both these stations over levels recorded in May or August are likely due to the higher levels recorded upstream in Bentley Lake. There was little increase in conductivity from station MM-3, at the upstream end of the tailings area to MM-4, located near the downstream end.

The increase in concentrations of uranium, iron, manganese and strontium in bottom water samples at station MM-5, at the northeast end of Bow Lake, was much more dramatic than changes in Bentley Lake. In May, levels of manganese increased from 68 µg/L at the surface to 6730 µg/L at the bottom, nearly a 100-fold increase. The increase in manganese concentrations was even more pronounced in the August sampling, when concentrations at this location rose from 14 µg/L at the surface to 11,300 µg/L at the bottom, an 800-fold increase. In contrast, levels of aluminum and iron increased only 2- to 3-fold, while levels of uranium increased from 23.8 µg/L to 123 µg/L, a 5-fold increase. However, in bottom water samples in August, the increase in uranium over levels in May was only 2-fold (from 43.6 µg/L to 88.3 µg/L), though levels in surface water had nearly doubled. Strontium concentrations also increased approximately 3-fold from the surface to the bottom at the east end of Bow Lake in both May and August. Concentrations of uranium in November were similar in both surface water and bottom water samples (56 µg/L vs 64 µg/L), but show an overall increase in surface water concentrations in the fall. Concentrations of manganese and strontium also decreased in bottom water samples during this period though, like uranium concentrations, while levels decreased in bottom waters, levels increase in surface water. The data also show that the chemical stratification apparent in the May and August sampling persists through the fall with a strong differential between surface and bottom water concentrations of manganese.

The data again suggest that the substantial increase in conductivity at the bottom of the water column is due primarily to the very high concentrations of manganese in the water. While bottom water concentrations decreased in November,

levels of uranium, strontium and manganese were still higher than surface samples. Concentrations of strontium and manganese in bottom waters in November were lower than in May or August, but still approx. 2-times and 31 times concentrations at the surface respectively. However, concentrations of all three metals increased in surface water samples, likely a result of at least partial mixing of the deeper waters during fall turnover. This mixing was most apparent in the uranium concentrations, which in the bottom waters, were similar to surface concentrations. The concentrations of the other metals, which were relatively much higher in bottom water than surface water compared to uranium concentrations, still showed a strong difference with depth.

Concentrations of all three metals remained elevated at the other two stations in Bow Lake (MM-6 and MM-7), and persisted into the two small lakes downstream of Bow Lake. At all four stations, concentrations of uranium, manganese and strontium declined only slightly from levels at station MM-5.

Elevated levels of uranium, manganese and strontium persisted downstream as far as the confluence with the Crowe River, though levels did decrease gradually with distance (Figures 11 to 14). However, both uranium and strontium concentrations were higher than the control stations all the way down Bentley Creek, and only at station MM-12, in the Crowe River, were concentrations similar to stations MM-LC (lake control) and MM-SC (upstream stream control). Levels of manganese in the water column, by comparison, though very high in bottom water samples from Bow lake, decreased much more rapidly (Figure 12), such that by station MM-10, concentrations were similar to the upstream stream control, station MM-SC.

Dyno Mine

The lake background for the Dyno Mine site was located in Brough Lake, which is situated upstream of both Farrel Lake and the tailings disposal area. Brough Lake is at the northern end of the mine property, and thus removed from impacts from the site. Concentrations of metals and nutrients in the water are considered as typical of background for this area. Concentrations of the parameters of concern (uranium, iron, manganese and strontium) were below the background levels at Siddon Lake (MM-LC), the local background site for the Madawaska Mine. Concentrations of these parameters were also similar at the next station downstream, DM-1, located just above the mine site.

Concentrations of the parameters of concern (uranium, iron, strontium) increased moderately in Farrel Lake and levels at both stations (DM-2 and DM-3) were very similar (Figures 11 to 14). At station DM-3, an increase with depth was noted in uranium from 0.45 µg/L at the surface to 1.44 µg/L near the bottom (3.5 times increase) in May, and from 0.68 (surface) to 1.82 µg/L (bottom) (2.7 times increase) in August. However, in November, concentrations in both the surface and bottom water samples were 0.82 and 0.8 µg/L respectively, indicating that complete mixing due to fall turnover had occurred. At this same station, iron increased with depth from 164 µg/L at the surface to 1420 µg/L in the bottom water in May (8.6 times) and from 256 to 2790 µg/L in August (10.9 times). Again, in November, concentrations in both surface and bottom water samples were nearly identical (702 µg/L and 698 µg/L). Manganese showed little difference between surface and bottom concentrations in May (112 vs 188 µg/L, i.e., 1.7 times), but levels in the bottom water increased substantially by August (from 29 µg/L at the surface to 828 µg/L at the bottom or an increase of 28.5 times), but were nearly identical to surface water concentrations in November (176 µg/L). However, all three metals showed a substantial increase in surface concentrations in November, after turnover, suggesting that the fall lake turnover contributes to significantly higher surface concentrations of these metals.

Unlike Bentley Lake and Bow Lake, concentrations of strontium increased only slightly with depth, and levels at the bottom (station DM-3) were less than 2-times the concentrations at the surface. By November, concentrations in surface and bottom water samples were nearly identical.

Concentrations of uranium, iron and manganese at station DM-4, in the beaver pond adjacent to, and at the outlet of Farrel Lake, were similar to surficial concentrations in Farrel Lake, and only approx. 2 times higher than at the stream control (station DM-SC). While concentrations of manganese decreased to near background levels at stations DM-5 and DM-6 in May, concentrations remained above background in August, and increased only slightly in November. Both uranium

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and iron showed only a slight decrease at station DM-5 in May from concentrations at DM-4, but higher concentrations than at DM-4 in August (uranium concentrations were as high as, or higher than concentrations in Farrel Lake). The elevated levels persisted into November, and even after turnover, levels were similar to those in August. For both uranium and iron, concentrations did not decrease until Eels Lake (station DM-8), where levels were similar to background. Concentrations of manganese, uranium and iron were all similar to background levels at station DM-8, and remained low at the other stations in Eels Lake (stations DM-9 through DM-11).

Bicroft Mine

The control for the Bicroft site was located in Centre Lake (BM-LC), which lies just north of the site. The control location was the large basin at the north end of the lake. Concentrations of uranium were lower in this lake than at either of the two other background stations, but both iron and manganese were similar to the other controls.

While uranium concentrations in surface and bottom water samples at station BM-1, located at the southwest end of Centre Lake, adjacent to the tailings dam, were similar to the control (DM-LC) during both the May and August sampling, concentrations of both iron and manganese increased significantly at the bottom in the August sampling (bottom water was not collected during the May sampling period). iron increased from 233 μg/L at the surface to 7160 μg/L at the bottom, the largest (30.7 times) increase that occurred at any of the stations sampled. manganese increased from 26 μg/L to 365 μg/L (14 times), which was the lowest increase in manganese of the three mining areas studied. U levels increased only slightly (from 1.5 μg/L to 2.0 μg/L).

During the May sampling period, one station, BM-2 was located inside the tailings pond ("Auger Lake"). Concentrations of U were only slightly elevated compared to Centre Lake control (BM-LC), and much lower than at any of the downstream sites below the Madawaska Mine. Station BM-2 was not re-sampled during any of the subsequent sampling periods.

Station BM-3 was located upstream of the mine site, below the outlet of Centre Lake, and thus served as the stream control for this mine site. Concentrations of uranium, iron, manganese and strontium were all similar to concentrations at station BM-LC.

Substantial increases in uranium, manganese and strontium concentrations in May, August and November were apparent at station BM-4, below the Pond A discharge. The highest concentrations of both uranium and strontium for this mine site component were recorded at this location. Uranium ranged from 5.75 μg/L in May to 9.56 μg/L in August, to 12.6 μg/L in November, though this is well below the maximum concentration in surface waters for this period, which was 56 μg/L in Bow Lake (though concentrations in Bow Lake bottom waters were even higher). Concentrations of strontium and manganese were substantially higher at station BM-4 in November (745 μg/L and 479 μg/L respectively) than in either May (475 μg/L manganese and 273 μg/L strontium) or August (412 μg/L manganese and 296 μg/L strontium).

By station BM-6, just at the mouth of Deer Creek, concentrations were 8.17 μg/L in May, 1.1 μg/L in August, but decreased to 1.96 μg/L in November. While much lower than at any of the other two mine sites, these still represent increases over background of 81-times (May) and 28 times (August) and 25 times (November). Though concentrations of manganese and strontium were relatively high at station BM-4, concentrations at BM-6 were only slightly above background in May and August, but for strontium increased by approximately 2-times by November.

Concentrations of all four (uranium, iron, manganese and strontium) were slightly elevated at station BM-7, in Inlet Bay (i.e., were similar to concentrations at BM-6) in May and August, but bottom water sampling in August revealed little difference between surface water and bottom water concentrations. While uranium and strontium concentrations were similar in November to levels in May, manganese concentrations were much higher than either of the two earlier sampling periods.

Concentrations of uranium and strontium at the other stations in Paudash Lake were slightly lower than at station BM-7

and showed little variation between sampling locations or with season, though concentrations remained above those in Centre Lake. Concentrations of manganese were typically higher than in the controls in November, but the higher concentrations in Lower Paudash Lake in comparison with Paudash Lake suggests there may be another source of manganese in this area.

3.1.3 Radionuclides

Results of the radionuclide analysis are also included in Table 3. Only radium-226 was measured in water samples, though both dissolved and suspended particulates were included in the analysis (Figure 13). The analysis was performed by the AECB lab in Ottawa.

Madawaska Mine

The occurrence of radium-226 shows a pattern of distribution similar to that noted for uranium and strontium (Figure 13). Levels of radium-226 increased in Bentley Lake (station MM-2) but only in bottom water samples. Surficial concentrations were similar to the upstream controls and were all below detection limits of 0.02Bq/L. A slight increase was noted at station MM-4 (0.03 Bq/L) and surface waters at station MM-5 (to 0.04 Bq/L), but a much larger increase was noted in the bottom water samples from MM-5. As with many of the other metals, a seasonal increase in bottom water concentrations at this station was also noted from May to August (to 0.27 Bq/L and 0.38 Bq/L respectively). Bottom water concentration decreased to a low of 0.06 Bq/L in November, which was only 3-times higher than surface.

Concentrations were also slightly elevated (0.16 Bq/L) in bottom water samples from station MM-6 in August (bottom water was not collected in May or November). In May, surface sample concentrations reached a high at station MM-8 (0.05Bq/L). Concentrations remained in the 0.03 to 0.05 Bq/L range from stations MM-7 through MM-11, and returned to below detection limits only at station MM-12, in the Crowe River during both sampling periods. The highest surface water concentrations (0.04 Bq/L) was noted in November.

Dyno Mine

Concentration of radium-226 in surface water samples increased to 0.18 in May at DM-2 from less than detection limit at background stations, but decreased slightly during the August sampling period (Table 3; Figure 13). Concentrations reached a high of 0.58 Bq/L in the bottom waters at station DM-3, though surface samples were similar to station DM-2.

Concentrations in samples below Farrel Lake, in Farrel Creek, were much lower (e.g., 0.08 Bq/L at station DM-5) in May samples, but increased during the August sampling period (to 0.21 at DM-5). Concentrations in Eels Lake were below detection limits during both May and August.

Bicroft Mine

The May sampling included the tailings disposal area (Auger Lake), and while the intent of this study was not to assess the mine sites, the results serve as a suitable reference point. Concentrations of radium-226 were higher in this lake (0.81 Bq/L) than at any other sampling location. The small creek below the Pond A outlet (BM-4) also had elevated levels (0.55 Bq/L), but below this point concentrations rapidly decreased, such that by station BM-6, levels were down to 0.04 Bq/L (Table 3; Figure 13). However, concentrations remained in the 0.02 to 0.03 Bq/L range through most of the Paudash Lake and Lower Paudash Lake sampling locations.

In August, concentrations at most stations were slightly lower. Concentrations at station BM-4, though lower than in May, were still higher than at any other site sampled in this study.

Bottom water samples were also collected in August at station BM-1, in the southwest arm of Centre Lake. Levels were

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slightly elevated over surface concentrations (below detection limits). During this same period, levels in Paudash Lake, with the exception of station BM-7 were all below detection limits.

3.2 Sediment Analysis

Results of the sediment sampling (sediment samples were collected only once, during the May sampling period) are presented in Table 4 and are shown on Figures 21 to 26. Analysis was undertaken for a suite of metals, including uranium, as well as radionuclides. The only metals that exhibited elevated concentrations were uranium, iron, manganese, strontium and radium-226.

Background concentrations of uranium ranged from 6 µg/g in Centre Lake (BM-LC) to 23 µg/g at Brough Lake (DM-LC). Concentrations in Siddon Lake (MM-LC), the background site for the Madawaska Mine, were midway in this range (13-14 µg/g). Concentrations in both Centre Lake and Brough Lake, showed very little change with depth down to 30 cm , but levels in Siddon Lake decreased form 13-14µg/g in the top 10 cm to 8 µg/g in the 20-30 cm section, and indicate that there may have been some influence on this lake from nearby mining activities. However, the concentration at the surface is still well within the range of the other background lakes, as noted above.

Madawaska Mine

Concentrations of uranium increased in Bentley Lake sediments over background, with the largest increase in the 0-10 cm section at both stations MM-1 and MM-2 (Figure 21). However, the concentration in surficial sediment at MM-2 was slightly more than double the concentration at station MM-1. The concentration of uranium decreased with depth such that at station MM-2, levels in the 20-30 cm section (30.5 µg/g) were one-eighth the concentration in the surface sediments (239 µg/g).

Sediment concentrations were lower at station MM-3 (approx. 2-3 times background) but increased again at station MM-4 (153 µg/g in the 0-10 cm section). However, at this location, subsurface concentrations were higher than in Bentley lake sediments, particularly in the 10-20 cm section (121 µg/g).

While surface concentrations at station MM-5 were similar to station MM-2 (239 µg/g) subsurface concentrations were considerably higher (462 µg/g in the 10-20 cm section). Concentrations remained high at station MM-6, though subsurface levels were substantially lower (91 µg/g in the 10-20 cm section).

Station MM-7, at the southwest end of the lake also yielded high concentrations in surficial sediment (169 µg/g), and slightly higher subsurface concentrations (115 µg/g) than at station MM-6. A similar distribution of uranium was apparent at both station MM-8 and MM-9. While concentration at MM-8 were slightly lower than in Bow Lake, levels were higher in both surface and subsurface section at station MM-9 (210 µg/g in the 0-10 cm section; 256 µg/g in the 10-20 cm section). Only at stations MM-10 and MM-12 (Crowe River) did concentrations decease to levels similar to those at the stream control (MM-SC).

The distribution of the other metals of concern followed a similar pattern to that noted for uranium. Strontium (Figure 24), iron (Figure 23) and manganese (Figure 22) increased in Bentley Lake sediments, with the highest increase in the surface sediments. However, at both stations, subsurface manganese concentrations were 2-3 times higher than the corresponding section at the control and up to 8-times higher for strontium. As noted for uranium, concentrations decreased at stations MM-3 and MM-4, but increased again at station MM-5 in Bow Lake. Unlike uranium, concentrations of these metals were lower at this station than in Bentley Lake, and ranged up to a high of 1300 µg/g manganese and 140 µg/g strontium in surficial sediments (vs. 2400 µg/g manganese at station MM-1 and 380 µg/g strontium at station MM-2).

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Concentrations remained elevated at stations MM-6 and MM-7, and were similar to concentrations at MM-5 in both surface and subsurface sections. While concentrations of both manganese and strontium decreased slightly at station MM-8, levels were higher in MM-9 sediments (1500 µg/g manganese in the 0-10 cm section; 150 µg/g strontium in all three sections).

Background concentrations for sediment radionuclides were 0.03 Bq/g for radium-226 and 0.2 Bq/g for uranium-238 (station MM-LC). A minor increase was noted in Bentley Lake sediments, where concentrations of radium-226 (Figure 25) and uranium-238 (Figure 26) rose to 0.16 Bq/g and 0.93 Bq/g respectively. Concentrations of both were highest in the 0-10 cm section, and near background in the 20-30 cm section.

A modest increase was noted at station MM-4 (0.24 Bq/g Ra-226; 1.43 Bq/g U-238), but the most notable increase occurred in station MM-5 sediments. Concentrations of radium-226 rose to 12.17 Bq/g in the 0-10 cm section and to 4.12 in the 10-20 cm section while uranium-238 rose to 2.49 Bq/g in the 0-10 cm section, and 4.3 Bq/g in the 10-20 cm section.

Concentrations of both were considerably lower at station MM-6. Radium-226 in the surface sample (0-10 cm) was 3.22 Bq/g, and had decreased to background levels in the 20-30 cm section. Uranium-238 in the surface sample was 2.44 Bq/g but had decreased to only 0.91Bq/g in the 20-30 cm section (vs. 0.1 in the corresponding section at the background station).

Concentrations at stations MM-7 through MM-9 were in the 0.65 to 1.1 Bq/g range for radium-226, and in the 1.3 to 2.1 Bq/g range for uranium-238. Only at stations MM-10 and MM-12 did concentrations fall to near background levels.

Dyno Mine

Background concentrations of uranium in Brough Lake ranged from 23 µg/g in the 0-10 cm section to 21 µg/g in the 20-30 cm section (Table 4; Figure 21). A slight increase in surficial concentrations was noted at station DM-1, a much larger increase occurred at station DM-2 (102 µg/g in the 0-10 cm section and up to 141 µg/g in the 20-30 cm section). It should be noted that the sediment at this location was comprised primarily of tailings material.

Concentrations at station DM-3, in the deep basin of the lake were lower (87 µg/g; 0-10 cm) than at station DM-2, and were similar to background in the 20-30 cm section. However, a substantial increase was noted at station DM-4, where surficial concentrations rose to 212 µg/g , while subsurface concentrations (10-20 cm) were 290 µg/g.

Concentrations downstream in Farrel Creek (DM-5 and DM-6) were much lower, and ranged up to a high of 67 µg/g at station DM-6. Concentrations in Eels Lake sediments (DM-8 through DM-11) were at (DM-8) or below background levels.

The distribution of manganese (Figure 22), iron (Figure 23) and strontium (Figure 24) showed only minor changes downstream of the mine sites as compared to the controls. Manganese concentrations at station DM-2 were lower than in the control lake while strontium levels increased by a factor of 2-3 and both stations DM-2 and DM-3. The concentrations of both metals actually increased only at stations DM-9, DM-10 and DM-11, in Eels Lake, well away from the mine site.

The distribution of radionuclides showed a slightly different accumulation pattern. Concentrations in the background stations (DM-LC and DM-SC) ranged from 0.3 to 0.4 Bq/g radium-226 (Figure 25), and 0.1 to 0.21 Bq/g uranium-238 (Figure 26). While both showed a slight increase at station DM-1 (up to 2-times higher), the highest concentrations were recorded at station DM-2 (Ra-226 was 11 Bq/g in the 0-10 cm section and 13 Bq/g in the 20-30 cm section), while uranium-238 ranged from 6.4 Bq/g in the 0-10 cm section to 8.6 in the 10-20 cm section. It should be borne in mind, however, that the substrate at this station was comprised mainly of tailings material.

Concentrations of both were still elevated at station DM-3 (9.2 Bq/g Ra-226 and 1.4 Bq/g U-238 in the 0-10 cm section), but decreased substantially with depth (0.34 Bq/g Ra-226 and 0.19 Bq/g U-238 in the 20-30 cm section). While the concentrations of some metals were elevated at station DM-4, levels of radium-226 were lower at this station than in Farrel Lake. The concentration in the 0-10 cm section was down to 1.6 Bq/g, while in the 20-30 cm section the level was 0.42 Bq/g. Concentrations remained in this range down to Eels lake. Surficial concentrations of radium-226 were slightly elevated at all stations in Eels lake in the 0-10 cm section when compared to the 20-30 cm sections

Uranium-238 concentrations increased slightly at station DM-4, but decreased downstream. Concentrations were similar to background at all stations in Eels Lake.

Bicroft Mine

Centre Lake sediments yielded the lowest background levels of all compounds analyzed (Table 4). Concentrations of uranium were consistently 6 µg/g in all three sections. A slight increase (13.3 µg/g in the 0-10 cm section) was noted at station BM-1, north of the tailings dam (concentrations in the 20-30 cm section were similar to the background station).

Station BM-2 located in the tailings disposal area yielded a sediment uranium concentration of only 58.2 µg/g, which was lower than some of the downstream locations such as BM-4, BM-6 and BM-7 (Figure 21). The uranium concentration at station BM-4 was 88 µg/g while at station BM-6 it was 346 µg/g.

Sediment concentrations of uranium in Inlet Bay of Paudash Lake were 134 µg/g in the 0-10 cm section and 41.7 µg/g in the 10-20 cm section, and even in the 20-30 cm section was still approx. 4-times higher (25 µg/g) than at the control (BM-LC). Concentrations were still higher than controls (BM-LC, BM-3) at station BM-8 and showed little variation among sections, while stations in Lower Paudash Lake (BM-10 and BM-11) were in the range of 26-30 µg/g in the 0-10 cm section and 13-15 µg/g in the 20-30 cm section.

Of the other metals of concern, only minor increases were noted in sediments below the mine site. Manganese increased at station BM-4 to 1100 µg/g from a background of 400 µg/g (Figure 22), while strontium (Figure 24) and iron (Figure 23) increased only in station BM-7 (Inlet Bay) sediments. Stations in Paudash Lake (BM-8 through BM-11) showed the highest accumulation of strontium (2-3 times background levels) while iron was highest (<2-times background) at stations BM-8 and BM-7 respectively.

Background concentrations of radium-226 (Figure 25) and uranium-238 (Figure 26) in Centre Lake ranged from 0.06 to 0.09 Bq/g and 0.1 to 0.19 Bq/g respectively. The tailings disposal area (BM-2) yielded concentrations of radium-226 of 9.9 to 14 Bq/g and uranium-238 of 9.7 to 12 Bq/g. Ra-226 concentrations were still elevated at station BM-4 (8.3 Bq/g) while U-238 concentrations had decreased to 1.6 Bq/g. While the concentration of radium-226 was relatively low at station BM-6, the sediment concentrations at station BM-7, in Inlet Bay, were similar to the tailings disposal area (14 Bq/g in the 0-10 cm section). Uranium-238 remained low, at 1.6 Bq/g in Inlet Bay sediments (BM-7) though concentrations at station BM-6 ranged up to 3.7 Bq/g.

Concentrations of radium-226 remained in the range of 0.7 to 1.1 Bq/g in the 0-10 cm sections at all stations in Paudash Lake, but decreased to background levels in the 20-30 cm sections. Uranium-238 concentrations were similarly elevated in the 0-10 cm sections and at or near background levels in the 20-30 cm sections.

3.3   Benthic Community Structure

Results of the benthic community analysis are presented in Table 5 (major benthic taxa) and Table 6 (detailed identification of organisms). All values in the tables are expressed as numbers of organisms per square meter.

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Madawaska Mine

Both the lake control and the stream control stations had relatively diverse faunas, though the stream control station (MM-SC) had a much greater variety of organisms than the lake control station (MM-LC). This would be expected due to the greater diversity of habitat types that occur in shallow waters. The lake station MM-LC, was characterized mainly by the oligochaetes and chironomid communities, though both were dominated by organisms typical of mesotrophic conditions (such as *Limnodrilus hoffmeisteri* among the oligochaetes and *Chironomus* and *Tanypus* among the chironomids (Saether 1975)).

The benthic communities at stations MM-1 and MM-2, in Bentley Lake, were considerably reduced in both density and diversity of organisms. The oligochaete community was entirely absent at station MM-1 and represented by only a few individuals in one replicate at station MM-2. Similarly, while the chironomid community at station MM-2 was represented by the same species as at station MM-LC, density was reduced. The chironomid community at station MM-1 was also reduced in diversity, and was represented by only two species, both of which are tolerant of low oxygen conditions.

The benthic community at station MM-3, below the outflow from Bentley Lake was relatively diverse, but was reduced in comparison to the stream control, station MM-SC. The benthic community at station MM-4 was similar in both density and diversity to station MM-3. Both were similar in terms of the species present, and were well represented by all of the major groups, though chironomids did predominate at station MM-4 (this group formed a relatively small percentage of the fauna at station MM-3).

The fauna at station MM-5, in the east basin of Bow Lake, was considerably reduced in both density and diversity of organisms. Except for a few individuals in one replicate, the oligochaete community was absent. The chironomid community, as well, was reduced to primarily *Tanypus*, which is a typical inhabitant of organic habitats, and is tolerant of low oxygen conditions. In addition, the sphaeriid community was also absent at this station, as well as at both stations in Bentley Lake.

However, the sphaeriid community was present at the remaining two stations in Bow Lake (stations MM-6 and MM-7), and in both cases formed a substantial part of the benthic communities. While the oligochaete community was better represented at station MM-6 (mean of 108 individuals per sq. m), the same community at station MM-7 was small. Similarly, the chironomid community was represented by only *Chironomus* at station MM-6 and both *Chironomus* and *Procladius* at station MM-7. While diversity was low, it was similar to both Bentley Lake and Siddon Lake (station MM-LC). Overall density of organisms was also similar between Bow Lake stations and Bentley Lake, though both were reduced in comparison to Siddon Lake.

The oligochaete community was also absent at station MM-8, in the small lake downstream of Bow Lake. This was a relatively shallow lake and is reflected in the greater diversity of some of the insect species, particularly the ceratopogonid community. However, the chironomid community was still represented primarily by the same two species that were common in the upstream lakes.

The benthic community at station MM-9 was much more diverse than any of the upstream lakes. This lake was very shallow (approximately 1 m) and this would account for the greater diversity of insect species, as well as the presence of gastropods. The chironomid community was more diverse than any of the stations upstream, and included a number of genera, such as *Cladotanytarsus, Polypedilum* and *Tanytarsus*, that are typical of such habitats. In total 10 genera of chironomids were recorded from this lake (as compared to 2-3 in the larger, deeper lakes).

An even more diverse benthic community was noted at station MM-10. This was essentially a shallow water (< 1m) flowing water habitat, similar to station MM-SC and yielded a similar fauna in both species present and density of organisms.

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The furthest downstream station MM-12, located in the Crowe River yielded a very diverse fauna typical of flowing water habitats.

Dyno Mine

The benthic community in Brough Lake (control station DM-LC) was characterized by the absence of the oligochaete community, with the chironomids and sphaeriids comprising nearly the entire fauna. The low numbers of species, and in particular the presence of *Stictochironomus* and *Tanytarsus*, suggests this is a relatively oligotrophic lake. Saether (1975) noted that certain species of chironomids, such as *Stictochironomus*, were typical of the deep profundal areas of oligotrophic lakes, which he classified as *Stictochironomus*-type lakes.

The stream control, station DM-SC, was relatively less diverse than the communities noted in the Bentley Creek/Crowe River watershed. In particular, the insect community was much reduced (only one species of Trichoptera was noted). However, the chironomid community was very similar to the Bentley Creek control as well as downstream stations in Bentley Creek (MM-10) and the Crowe River (MM-12).

Station DM-1, located in the small pond downstream of Brough Lake (DM-LC) was similar in density to station DM-SC, though the fauna was slightly more diverse, particularly in terms of the insect species. Diversity of the chironomid community was similar, though there was a slight shift in the species present to more standing water types.

Station, DM-2 located in Farrel Lake just below the tailings dam, yielded a slightly more diverse fauna than the control (DM-LC). Notable was the presence of the mayfly *Hexagenia*, which typically prefers sandy-silty substrates (this species needs a firmer, more cohesive substrate in order to construct burrows in the sediment). The higher content of fine tailings material noted in these sediments would tend to render these sediments more suitable to this species. The chironomid community was also relatively diverse (7 different species/genera) and was typical of relatively shallow areas of lakes (e.g., *Cladopelma*, *Harnischia* and *Tanytarsus*). A relatively limited oligochaete community was also present.

The benthic community at station DM-3, located in the deep basin of Farrel Lake, was reduced to primarily chaoborids and a few chironomids. Only two species of the latter were present, and the fauna suggests that low oxygen is a factor in this basin.

The fauna at station DM-4 located in the adjacent beaver pond was restricted primarily to the chironomids, of which a relatively diverse community was noted. Notable was the absence of insect species, which would have been expected in such a shallow organic habitat (in habitat characteristics, this pond would have been similar to station MM-9).

Station DM-5 yielded a much more diverse fauna, more typical of shallow flowing waters than at station DM-4. The benthic community at this station was similar in both density of organisms and species composition with station MM-10. A similar fauna was also observed at station DM-6.

Station DM-8, located near the mouth of Farrel Creek in the shallow bay of Eels Lake, yielded a very diverse fauna which included a wide range of chironomid species typical of shallow lake habitats, as well as the mayfly *Hexagenia*.

The remaining three stations in Eels Lake (DM-9, DM-10 and DM-11) were all similar and in terms of fauna were typical of deep oligotrophic lakes. The chironomid fauna, which comprised over 50% of the total fauna, was in turn dominated by *Stictochironomus*, which as has been noted earlier is typical of deep oligotrophic lakes.

Bicroft Mine

The background location for the Bicroft site was in the north basin of Centre Lake. The fauna at this location consisted mainly of chaoborids with a few chironomids and a very small population of oligochaetes. The reduced chironomid

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population, and the high density of chaoborids suggest that this basin, like the other deep lake basins in this study, suffers from low oxygen at least at certain times of the year. A similar situation appears to exist at station BM-1, in the southwest basin of Centre Lake adjacent to the north tailings dam.

While the benthic community was reduced in the tailings pond (station BM-2), and is not the subject of this investigation, the presence of the mayfly *Hexagenia* was noteworthy. As in Farrel Lake, the presence of tailings material likely creates a more suitable burrowing substrate for this organism. However, the reduced number of other invertebrates as compared to other similar habitats in the study area suggests that the substrate does not form an ideal habitat for many other species.

Station BM-3 served as the stream control for this site, and yielded a very diverse fauna of a mix of both flowing water and standing water species.

The benthic fauna below the outflow from Pond A, located in a very small stream, yielded a much less diverse fauna (only 5 species were recorded vs. 24 at station BM-3). Faunal density was also approximately 25% of the density at station BM-3. As noted at the other mine sites, stream habitats in this area tend to have diverse benthic faunas, and the lack of diversity at this site is noteworthy.

In contrast, the benthic community at station BM-6, near the mouth of Deer Creek, was more diverse and resembled the community at the stream control (BM-3), though density of organisms remained well below the levels recorded at station BM-3. The diversity of insect groups, and in particular the mayflies, was reduced, as was the diversity of chironomids, though the species present were similar to those at station BM-3.

The benthic community at station BM-7, located in Inlet Bay (Paudash Lake) was composed primarily of chaoborids, which suggests that this basin also suffers periods of low oxygen in the bottom water. In contrast, the benthic community at station BM-8, in a much shallower basin, was more diverse, with the presence of both amphipods and isopods. It should be noted that this area experiences significant weed growth in the summer which would provide suitable habitat for these organisms. This was also reflected in the more diverse chironomid community at this site as well.

Station BM-9 was located in the deep south basin (Joe Bay) in a sandier substrate, and this is also reflected in the relatively larger oligochaete and chironomid communities.

The remaining deep basin stations (stations BM-10 and BM-11) had similar benthic communities that were dominated by the chaoborids and secondarily by the chironomids. These were both deep stations (12m or more), and likely experience lower oxygen levels, particularly during the summer thermocline formation. The chironomid fauna suggests that this lake is less oligotrophic than the other deep lakes, since both *Procladius* and *Tanytarsus* formed the majority of the chironomid fauna. Stictochironomus was noticeably absent at these stations, and suggests a slightly higher organic input than Centre Lake or Brough Lake.

3.4   *Laboratory Sediment Bioassay Testing*

3.4.1   Water Quality Test Parameters

Conductivity, pH, total ammonia, un-ionized ammonia and dissolved oxygen parameters were periodically measured on the overlying water for each test species and summarized in Table 7. Values are reported as mean ± standard deviation.

The pH recorded among the reference and nine test sediments for the mayfly, midge and minnow tests varied considerably. While pH remained relatively constant (ranged between pH 7 and pH 8) at the majority of stations, there was a considerable decrease in pH over the period of the test (21-days) in both the fathead minnow assays at stations MM-5, MM-7, DM-3 and BM-7, and the mayfly assays at stations MM-7, DM-3, BM-7 and the reference station BM-LC. The results are presented in Table 7, and show the lowest recorded pH (3.74) occurred at station DM-3 in the mayfly

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assay. Conductivity readings were also variable and ranged between a low of 215 µmho/cm at the reference station to a high of 1101 µmho/cm in station MM-5 sediment and suggest there may have been release of ions from the sediments during the test period. Overall results are reasonably consistent with results from bulk sediment analysis (Section 3.2). Dissolved oxygen within the test jars remained above the minimum acceptable level (>4 mg/l) throughout the test (OMOEE, 1994). Test temperature was near 20°C for each bioassay.

The amount of total ammonia (NH_4), along with the converted un-ionized ammonia (NH_3) based on temperature and pH, was also recorded in Table 8. The lowest un-ionized ammonia concentration was reported for the negative control exposure in the mayfly and chironomid toxicity test (<0.003 mgNH$_3$/L). Un-ionized ammonia concentrations measured in the test sediments were either within twice the PWQO of 0.02 mgNH$_3$/L or within twice the concentration reported for the reference sediment exposure. The un-ionized ammonia concentrations are well below cited acute and chronic concentrations for fathead minnows (Thurston *et al.*, 1983; 1986) and midge larvae (Schubauer-Berigan *et al.*, 1995; Whiteman *et al.*, 1996), recorded for, or extrapolated using the actual test temperature and pH.

3.4.2   Sediment Characterization

The following sections summarize the sediment physical and chemical parameters to aid in the interpretation of the biological toxicity results. Chemical analysis is based on the sediment prepared for toxicity testing and results may differ from those reported for any field samples collected concurrently. Any dissimilarities are likely due to *in-situ* chemical heterogeneity and/or sampling depth and sample handling (ASTM, 1997b).

Physical and Nutrient Properties

Sediments were characterized for % sand (2mm-62µm), % silt (62-3.7µm), % clay (3.7-0.1µm), % loss on ignition (LOI), total organic carbon (TOC), total phosphorus (TP) and total Kjeldahl nitrogen (TKN) (Table 8).

The control and test sediments were characterized as either silty, clay loam or sandy loam depending upon the relative proportion of fine and coarse-sized particles (Millar *et al.*, 1965). All stations (as well as the negative control), with the exception of sediments from station BM-6, were predominately comprised of silt and clay fractions (>75%). Station BM-6 contained 52% sand. While silt and clay sized particles comprised most of the sediment at station DM-2, the sediments contained a visible amount of tailings-like material, and this is also reflected in the relatively lower TOC of these sediments, compared to those from the other stations.

The sediments were generally dark brown in colour with the exception of sediments form the deep basin of Farrel Lake (station DM-3) and from the east basin of Bow Lake (station MM-5), which were black in colour.

Trace Metal Sediment Concentrations

Bulk sediment samples were analyzed for 13 trace metals (Table 9). The sediment metal concentrations were compared to Severe Effect Levels (SEL) and Lowest Effect Levels (LEL) of the Provincial Sediment Quality Guidelines (PSQGs) (Persaud *et al.*, 1993).

Exceedences of the SEL were noted for nearly all test sites for iron while three sites exceeded the SEL for manganese and an additional two sites exceeded the SEL for lead (stations DM-2 and DM-4).

The distribution of uranium varied among the test sediments. Sediment concentrations were highest at station MM-5 (540 µg/g), station MM-7 (474 µg/g) and station BM-6 (491 µg/g) and were significantly higher (by nearly two orders of magnitude) than reference sediments from station BM-LC (5.5 µg/g). Levels at the remaining station were in the range from 100 to 300 µg/g except at stations DM-2 and BM-7, where levels ranged from 78 µg/g to 83 µg/g respectively.

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Organic Chemical Sediment Concentrations

Concentrations of 16 organochlorine pesticides and 11 chlorinated organic compounds in all sediment samples were below the respective detection limits (Table 11).

3.4.3 Mayfly (*Hexagenia limbata*) 22-day Lethality and Growth Results

The biological data for the two endpoints, mortality and growth, are summarized in Table 10 and are shown on Figures 27 and 28. Differences in mayfly toxicity were compared among all sites and mortality was statistically higher at two test sites (ANOVA; p=0.0002). Station BM-6 sediment was moderately toxic to mayflies with 63% mortality and station DM-3 sediment showed a significant toxic effect with 100%mortality, as compared to the remaining four test sites (Range: 0% to 16% mortality; LSD *t*-test). As well, the average percent mortality for each test sediment was individually compared to the reference control sediment using Dunnett's *t*-test to determine the degree of difference in biological response between the test sediment to that associated with local background conditions. Percent mortality in the reference control (station BM-LC) was 26.6% and was significantly different than station BM-6(63% mortality) and station DM-3 (100% mortality), but was not significantly different from station MM-5 (40% mortality).

Mayfly body weights varied significantly among test and control sediments (ANOVA; p<0.0001). Final growth measurements fell into two distinct groups. The best nymphal growth occurred at three sites (stations MM-2, DM-4 and BM-7) which exceeded the amount of growth observed in the reference sediment. The remaining test sediments had mayfly weights that were comparable to the negative control weight (6.39 mg w.w) or the reference station weight of 8.68 mg w.w.. Therefore, at a limited number of stations was a doubling or more of the initial starting weight (mean starting weight was 5.63 mg w.w.), (a doubling of weight in mayflies is often observed over a three week period) which represents above average growth. Station MM-5 had the poorest mayfly growth (a 12% increase), which was similar to the negative (Honey Harbour) control, but was lower than in the reference control where mayflies increased in body weight by 54%. In fact, sediments from stations MM-5, MM-7 MM-9 and DM-2 all showed lower growth than the reference control.

In assessing the growth data, the reference sediment is considered a more suitable control in measuring relative differences in mayfly growth. This is due to the similarities in sample collection, handling and storage methods used for reference and test sediments, as compared to those used in the collection of the negative control sediment. Mayfly growth depends on the quality and quantity of detrital material found in the sediment, since a supplemental diet is not provided during the test. The relatively low body weight of 9.3 mg measured for the negative control animals is likely attributed to the extended sediment storage time (~12 months) versus the freshly collected reference and test sediments (~ 3 weeks). Ideally all sediments should be subjected to the same storage duration since prolonged storage may affect the nutritive value of the sediment, thereby affecting organism feeding/growth rates (Boese *et al.*, 1996).

3.4.4 Chironomid (*Chironomus tentans*) 10-day Lethality and Growth Results

Results for chironomid growth and lethality are reported in Table 10 and shown on Figures 27 and 28. Chironomid control percent mortality was 2.2% and 15.5% for the reference and negative control, respectively. All of the test sediments resulted in good survival (Range: 4% to 13% mortality) and were ranked similarly. These values fell within the acceptable test criterion of 25% mortality.

Midge growth varied among the test sediments (ANOVA; p<0.0001). The best growth occurred for stations MM-2 and MM-9, and both showed higher growth than in the other test sediments and the reference control sediments. The remainder of the test sediments resulted in growth that ranged between that recorded for the negative control and the reference control. The average weights recorded at these sites were within the range of control weights and do not suggest growth impairment.

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3.4.5 Fathead Minnow (*Pimephales promelas*) 21-day Lethality Results

Juvenile fathead minnow percent mortality data are reported in Table 10. Minnow survival was 97% to 100% in the negative control and reference sediments. Mortality at most of the other stations was also in this range with the exception of stations MM-5 (16.6%), MM-7 (33.3%) and DM-3 (100%). Only station DM-3 mortality was statistically significantly different from the other stations. A rough estimate of fish wet weight was made on pooled samples on Day-21. The final fresh weights for each batch of test animals did not differ more than 12% of the negative control weight. The equality in minnow weight across sites suggests the fish were feeding normally and the sediments were not contributing to underlying stress, assuming body weight is an indicator of fish condition.

3.4.6 Quality Assurance Data

An evaluation was made on the biological data in order to determine the repeatability of the test results (Table 10). Percent coefficient of variation (C.V.) for mayfly and midge growth was 22% and 17%, respectively. Despite the higher C.V. reported for mayfly mortality (25.6%) and midge mortality (77.9%), the ability to distinguish a significant effect among sites remained high. In fact, all five test endpoints were effective in measuring differences among sites (D.P. = 4 to 9). Overall, *Hexagenia* appeared to be the most sensitive test species given its ability to identify impaired sites.

Each of the lethality responses was effective in detecting differences in lethality among sites. The minimum significant difference or MSD is a quantitative measure of test precision which describes the ability to detect a significant effect in the paired response between the control versus the test sample. The MSDs were 25%, 15% and 44% for the mayfly, midge and minnow assays, respectively. These values did not match those quality standards observed during previous OMOE toxicity tests e.g. average MSD = 13% for *Hexagenia* (n=20), MSD = 20% for *Chironomus* (n=21) and MSD = 20% for *Pimephales* (n=15) (D. Bedard, OMOE, unpublished data). The higher detectable significance criteria for the mayfly and fathead minnow lethality responses may have compromised the statistical power of the test. This was apparent for one site (station MM-5) in the mayfly test and one site in the minnow test in which 40% mortality and 33% mortality respectively were deemed insignificant relative to one of the control sediments due to the degree of error associated with the mean. All other non-significant lethality responses were below the acceptable control criteria and not affected by the MSD.

3.4.7 Chemical Bioaccumulation in *Pimephales promelas*

The examination of chemical availability to aquatic organisms is valuable for assessing the potential for chemical transfer through the food web. The primary objective of this test design is to make general observations on whole organism tissue concentrations as they relate to bulk chemical concentrations in the sediment and differences in chemical uptake among sites. Surviving fathead minnows were submitted for the analysis of uranium in body tissues (all values are based on whole-body tissue residues). Values are provided as wet weight and converted using a dry wight to wet weight ratio of 0.15 in the calculation of biota-sediment accumulation factors or BSAFs.

The potential sources of inorganic metals to forage fish include direct ingestion of the sediment and uptake from the overlying water. Factors that control chemical accumulation by forage fish include those that affect chemical speciation, adsorption and desorption, such as sediment organic content, redox potential, pH, iron and manganese oxides and particle size distribution (Luoma, 1983). The presence of sediment sulphide as measured by AVS has also been suggested as an important factor in describing the chemical bioavailability of certain divalent trace metals from sediment (Ankley, 1996). Biotic factors affecting uptake include metabolism and metal specific toxicokinetics (Campbell *et al.*, 1988).

Table 12 reports the uranium tissue concentrations (wet weight) and associated standard deviations measured in surviving juvenile fathead minnows. Whole-organism chemical concentrations are based on triplicate samples. There were significant differences in fish tissue concentrations between the control(s) and test sediments at all stations, and significant differences in tissue concentrations among test sediments as well (One-way ANOVA; p=0.00001). Tissue concentrations of uranium at each test exposure were higher than the tissue concentration found at the reference site by

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at least an order of magnitude.

Concentration factors were calculated to assess the relative availability of each trace metal for the test and reference sediments. The biota-sediment accumulation factor (BSAF) is defined as the ratio of inorganic chemical concentration in the fathead minnow to that in the bulk sediment (Table 9) (Lake *et al.*, 1990). Each individual replicate that was analyzed consisted of ten individual animals.

$$BSAF = C_t / C_s$$

where,

C_t = tissue metal contaminant concentration (μg/g tissue, dry weight)
C_s = sediment metal contaminant concentration (μg/g sediment, dry weight)

BSAFs were under 0.06 at all stations except BM-6 and exceeded the reference control BSAF of 0.03 at only three locations. However, station BM-6 sediment yielded a BSAF of 0.53, which was approximately an order of magnitude higher than most of the other stations. Despite the low degree of metal availability as indicated by the BSAF, those sites with elevated sediment uranium concentrations, still resulted in substantially higher fish body burdens, relative to the reference fish. BSAFs > 1.0, indicating that the chemical found in the organism surpassed those levels found in the bulk sediment, were not found at any of the test locations.

3.4.8   Spatial Trends in Sediment Toxicity

The biological and chemical data were synthesized in order to determine the spatial trend in sediment quality for the nine sediment samples selected for laboratory toxicity testing (Table 13). The main factors in assessing sediment quality include sediment metal concentrations relative to the PSQGs, tissue uranium concentrations significantly higher than reference and the total number of significant biological responses measured in the bioassays.

Sediment rankings varied widely according to the frequency and intensity in biological response for the mayfly and midge assays. Test sites that were regarded as impacted, due to the differences in biological response between the test and reference sediment, were stations DM-3 and BM-6. Station MM-5 may also have been slightly impacted given the incidence of low growth of both benthic invertebrates and the increase in mayfly mortality. Severity of effect was high for station DM-3 where mayfly and fathead minnow lethality was the highest reported (100% mortality). Station BM-6 was also impacted as denoted by increase mayfly mortality, and significant uptake of uranium by the fathead minnows.

4.0   Discussion

4.1   Surface Water

Madawaska Mine

The May sampling data show that elevated levels of some metals are present in the bottom water samples of Bentley and Bow Lake in the spring after the spring turnover. Since turnover typically results in a mixing of the water column, the presence of higher concentrations of manganese, strontium, uranium and iron in the bottom water indicates that stratification is present in the spring and persists past the turnover; i.e., there is incomplete mixing of the water column. Two areas in particular stand out: the south basin of Bentley Lake and the east basin of Bow Lake. Both showed strong increases in conductivity with depth, coupled with substantial increases in the concentrations of some of the metals, in particular manganese, iron and strontium and to a lesser extent, uranium and radium-226. These conditions were already present during the spring sampling, became even more pronounced during the summer, when presumably temperature

induced stratification was superimposed on the already pre-existing chemical stratification, and persisted into the fall past the fall lake turnover. Thus, the data suggest that these basins are more or less permanently stratified, with elevated bottom water concentrations of metals of concern.

Lake turnover in the fall results in higher concentrations of metals of concern in the surface water samples, presumably due to mixing of bottom waters high in metals with surface waters. The increase in land runoff that typically occurs in the fall due to higher rainfall, could also contribute elevated levels of metals to surface water. Therefore, while the concentrations of metals were more evenly distributed throughout the water column after turnover in the fall, the overall results was high surface water concentrations both in Bentley and Bow Lakes, as well as downstream. The data suggest that losses from the site, via surface runoff and leaching, as well as re-mobilization of metals from sediment (particularly during periods of redox change at the sediment surface, see next section) is an on-going process that continues to contribute metals such as uranium, strontium, manganese and iron to the lakes in the system.

While direct dissolved oxygen measurements were not taken, the conductivity measurements, coupled with the analytical results for both surface and bottom water indicate that certain basins, such as the south basin of Bentley Lake (MM-2) and the east basin of Bow Lake (MM-5) are more or less permanently stratified. The increase in bottom water manganese concentrations is similar to observations by Stauffer (1985) on Lake Mendota (Wisconsin), where manganese levels increased in bottom water during low oxygen conditions. Stauffer (1985) suggested that the most likely source of the elevated manganese was from release from sediments under the changing redox. Forstner and Wittman (1981) note that manganese oxides and sulfides are generally more soluble than iron oxides or sulfides. As a result, under redox changes these would be released first. Stauffer (1985) also notes that other metals that co-precipitate with the manganese oxides are also likely to be released to the water column as the oxides dissolve and sulfides form.

In Bow Lake, as concentrations build up in the deeper waters in the summer months, due to temperature induced stratification, the lake area affected increases. It appears that much of the lake area is mixed during fall turnover, but in the deeper basins noted, the mixing is only partial and does not extend to the bottom. Thus, some areas of stratification persist past the turnover. Under low oxygen conditions that are expected to persist without full turnover (there is no mechanism by which oxygen levels in the deeper water can be replenished except through passive diffusion from overlying water, which is a very slow process) there can be significant release of metals from bottom sediments, which would aid in the increase in bottom water concentrations. The decrease in metals concentrations in surface water samples during the summer suggests that surface runoff is a minor contributor, otherwise there should have been an increase in surface water concentrations during summer, since the summer of 2000 was a particularly wet summer. Thus, leaching and release from bottom sediments could be the major sources of metals to the water column.

However, additional external sources of metals to Bow Lake also exist and the increase in bottom water concentrations of these metals is likely not due solely to internal cycling. The PWQMN sampling data show that concentrations of many of the metals of concern increased at station MM-4 over levels in Bentley Lake (Figures 15 through 19). Thus, there appears to be a source of these metals to Bow Lake from the mine site.

In Bow Lake, the evidence suggests that the anoxic layer does not disappear entirely. The data suggest the layer is reduced in the fall, after turnover, but that there is incomplete mixing. As a result, the lake appears to enter the winter season already stratified. Since stratification of lakes under ice is a common occurrence, there is little likelihood that further mixing of the deeper layers would occur, and in fact the data from May suggest that the stratification persists until the spring, when again there appears to be incomplete mixing. The most plausible description of events is that manganese oxides (and any co-precipitated metals such as U and Ra-226) from the oxygenated layer precipitate to the bottom (these would likely originate as free and/or complexed manganese from Bentley Lake and the mine site via Bentley Creek). As these settle down through the anoxic layer, the manganese oxides would undergo dissolution, with release of manganese and any co-precipitated metals to the bottom water. During the summer and winter months, as the layer of anoxic water builds up, there would be more release to the upper layers, which partially mixes in the spring and fall, resulting in higher concentrations in the surface waters. While the likely cause of this permanent stratification was the initial influx of metals from the mining operation after activities commenced in the 1950's, this now appears to be a self-perpetuating process. The metals released to the water column and mixed with the oxygenated surface waters would be free to again form

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manganese oxide complexes, and begin the cycle over again. However, some of the metals would by now have been carried out of this eastern basin and into other parts of Bow Lake, distributing the metals outside of the eastern basin. If bottom waters in these areas did not undergo seasonal periods of anoxia, the complexes would likely remain in the sediments. Finally, some of the metals released to the surface waters would be flushed out of the lake and down to the next series of lakes, where complexation and precipitation would result in the elevated sediment concentrations observed at these sites.

In those lakes where there is complete mixing of the water column during turnover, such as Bentley Lake, in addition to external sources of metals, the sediment bound manganese, and any co-precipitated metals, could be released during periods of anoxia when the manganese oxides undergo dissolution. Since the bottom waters in the eastern basin of Bow Lake appear to be permanently stratified, sediment release by this mechanism is not expected to be a major source, since under conditions of persistent anoxia, the sediment manganese and other metals are expected to form stable sulfide complexes. Only when redox conditions change (i.e., if oxygenated waters were introduced) would there be changes in metals complexation with resultant release of metals to the water column

The PWQMN data show that there has been a steady discharge of metals in the water from Bentley and Bow Lakes to lakes further downstream, and ultimately to the Crowe River system as well (Figures 15 to 19). The PWQMN data also show that current levels are significantly below the discharges that have occurred during the period when the mines were active. However, the recent data also demonstrate, that over approx, the last 10 years there has been little or no reduction in the levels of metals discharged from Bow Lake. Thus, the processes that have resulted in release of metals to the system are still on-going.

Concentrations of uranium in surface water exceeded the interim PWQO of 5 ug/L at a number of locations. Concentrations of radium-226 did not exceed the PWQO of 1.0 Bg/L at any of the locations.

Seasonal trend data from the PWQMN indicate that historically, there is a trend for increasing concentrations of uranium at the discharge from Bow Lake from May to November (this parallels the data in this report and suggests that the results of the 2000 sampling are not unusual) (Figure 17). Again, this suggests that fall mixing of the water column contributes to elevated levels in the water column which exit the system via the outflow (PWQMN station).

Elevated levels of radium-226 at MM-4 may be due to runoff/leaching from the tailings area. Levels appear to decrease in the spring (April), and may be related to dilution due to spring runoff (Figure 18). Concentrations then appear to steadily increase during the summer and early fall (typically the low rainfall months, which translates into lower dilution), at which point concentrations begin to decrease (likely coinciding with the increase in precipitation in the fall) to a low in December (i.e., after freeze-up - this would coincide with the decrease in runoff and also a decrease in flow in Bentley Creek due to winter freeze-up). The observed increase in May could be due to runoff/ leaching from the tailings area due to spring snow melt carrying additional metals to the receiving water (which may also account for the high metals levels in bottom water during the May sampling).

The seasonal distribution of radium-226 in water at station MM-3 indicates that some of the increase in radium-226 concentrations observed at station MM-4 may be due to higher levels in the creek itself, but that this does not account for all of the observed increase. Since MM-3 is below the discharge from Bentley Lake, the results indicate that an increase in radium-226 concentrations does occur in Bentley Lake during the summer months.

Seasonal changes in Bow Lake, as measured at the discharge at Hwy 28, showed a less pronounced fluctuation, but did show consistently higher levels than at the upstream stations, except during the summer months (Figures 17 and 18). The increase in concentrations at station MM-4 during June to Sept, is not reflected in surface water concentrations at MM-7/8. However, the increase in radium-226 concentrations in bottom water samples from Bow Lake suggests that part of this additional inflow from upstream may end up in the deeper sections of the lake basin, to be released only when the lake undergoes turnover in the fall. The higher concentration in surface water in November may result from mixing of surface water with bottom water (concentrations in bottom water samples in Nov. 2000 were similar to surface water, and lower than in either May or August). This is also reflected in the higher concentrations at the lake outlet (MM 7/8),

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than upstream (which suggests more radium is leaving the lake during certain periods of the year, than is entering the lake via Bentley Creek) (Figure 18), further suggesting there is a reservoir of radium-226 held in the lake, or there are other significant sources, such as seepage or groundwater transport.

Seasonal changes in uranium concentrations showed only a slight increase below the discharge from Bentley Lake, indicating there is only a slight increase during the summer months and into the fall (Figure 17). A much larger increase was observed at station MM-4, which shows a peak in the summer months and during the fall and a low in March, the latter likely a reflection of winter freeze-up conditions. Concentrations were much higher in Bow Lake at the lake outlet, with a strong increase in early spring (May) and consistently high levels until late fall (Nov.- Dec) when a small increase (likely due to fall turnover) was noted. As with radium-226 concentrations, the results indicate that there is a substantial reservoir of uranium in Bow Lake or that there are other significant sources aside from Bentley Creek that would account for more uranium leaving the lake than is entering via Bentley Creek.

The distributions of both radium and uranium suggest that mixing of bottom water contributed to elevated levels in Bow Lake during the late fall, while the increase in the spring from low levels in the winter months could be due to a combination of spring runoff, other sources such as seepage, and lake turnover in the spring.

The increase in manganese concentrations in bottom water during the summer months suggests a possible explanation for the pattern of manganese distribution as determined from the PWQMN data. Since manganese concentrations in Bow Lake showed little or no increase over the summer, despite increasingly higher concentrations in Bentley Creek, and in fact concentrations decreased over the summer as compared to the spring, it is possible that much of the manganese contributed via Bentley Creek has gone to fuel the substantial increase in manganese concentrations in the bottom water (up to 11,300 ppm during August, 2000). The increase in manganese concentration in Bow Lake in November coincide with the decrease in bottom water concentrations of manganese observed during this study, and suggests that much of the manganese contributed via Bentley Creek is held in the bottom water until the fall turnover.

Dyno Mine

Surface water concentrations indicated that the compounds of concern in Farrel Lake were manganese and iron and to a lesser extent, strontium and uranium. While concentrations of all four were elevated above levels at the background site (Brough Lake), concentrations even in bottom water samples were substantially lower than in Bentley Lake or Bow Lake samples. While both iron and manganese concentrations were 2-3 times higher in bottom water samples at station DM-3 in both May and August, concentrations in November samples were similar to surface water. Thus, it appears that complete mixing of the water column does occur at least in the fall, and suggests that the spring turnover may be less effective in ensuring complete mixing of the water column. While concentrations of both manganese and iron were similar in both surface and bottom water samples in November, overall the concentrations were much higher in November samples. There are two possible sources of the increased manganese and iron: increased runoff from the mine tailings areas and; potential release from sediments during periods of stratification where changes in redox conditions can result in liberation of bound metals from the sediments.

While there was a slight increase in uranium concentrations in November samples, and also in bottom water samples in both May and August, levels did not exceed the interim PWQO in any of the samples. Thus, while it appears there is a small flux of uranium, or possibly additional uranium that is carried in during increased flows during the fall (due to increases in precipitation), these levels do not appear to be of concern.

Strontium concentrations were also elevated in bottom water samples in May and August from Farrel Lake but concentrations were well below the levels recorded in the bottom waters of Bow Lake. Radium-226 concentrations were elevated in bottom water samples in May (highest of any of the sites) and also in August. However, none of the samples exceeded the PWQO of 1 Bg/L.

In comparison to Bow Lake, Farrel Lake showed a similar pattern of metal mobility and flux, but with iron as the primary

metal rather than manganese. The increase in iron concentrations in Farrel Lake bottom waters suggests external sources, rather than internal cycling from the sediments. As noted earlier, manganese oxides and sulfides are less stable than iron oxides or sulfides. As such, if the iron in the bottom water was primarily due to release from sediments, a similar increase in manganese levels in bottom water samples would be expected. The same mechanisms that apply in Bow Lake are also likely acting in this area. The process can be described simply as an influx of iron-rich waters from the tailings area, which in the oxygenated surface waters forms oxides and hydroxide complexes. As these settle into the anoxic deeper waters, the oxides undergo dissolution, releasing iron to the water column (as well as any metals co-precipitated with the iron-oxides). During the spring and fall turnovers, oxygenated waters appear to mix the entire depth of the lake, with the result that iron and other metals will form oxide/hydroxide complexes (among others, such as carbon) in the sediments. As conditions become anoxic during the summer months, the oxides undergo dissolution, and iron and other metals are released to the water as iron and other sulfides form. When the lake turns over again, the bottom water is mixed with the surface water. At the same time, oxygenated water reaches to the deeper basin sediments. As a result, iron and other metal sulfides that formed in the surface layers of the sediment, would undergo dissolution, prior to the re-forming of oxides. During this phase, metals could again be released to the overlying water.

Bicroft Mine

While concentrations of some metals were elevated below the Bicroft site, in particular, in the small tributary that drains Pond A, as well as in Deer Creek, near the mouth, concentrations in the first receiving water body, which was Inlet Bay of Paudash Lake, were generally low. There was no apparent summer increase in bottom water samples over concentrations in surface water samples except for a slight increase in manganese concentrations, but overall, levels in Inlet Bay for manganese were at or below background levels.

Uranium levels below the Pond A discharge were elevated above background levels, and also exceeded the interim PWQO of 5 ug/L It is interesting to note that levels in this tributary were higher than in the tailings pond (BM-2), but were much lower than surface water concentrations in Bentley Lake and Bow Lake. The data suggest that discharge from Pond A, rather than the tailings pond ("Auger Lake"), contributes elevated uranium levels to the system.

The sampling program also identified the discharge from Pond A as a source of radium-226 to the system, though none of the concentrations recorded, even in the tailings disposal area, exceeded the PWQO of 1 Bq/L.

Overall, concentrations in off-site receiving waters of all four metals were lower than at the other sites. Concentrations of radium-226 were also lower than at the other mine sites, but since none of the sites exceeded the PWQO, this was not a concern.

However, additional studies (R. Bradley MNDM, Pers. Comm) have noted that a significant amount of water from the site drains to a wetland area to the east of the Bicroft mill site. This wetland area drains directly to Inlet Bay, and high concentrations of uranium have been noted in this area in the past. Investigative work is continuing on this site (R.Bradley, Pers. Comm).

Analysis of PWQMN data, while incomplete, suggest peaks in uranium discharge occur during the summer and fall months (Figure 17), which coincides with the increased uranium recorded in the water column during the August 2000 sampling. Uranium concentrations in the water column exceeded the Interim Provincial Water Quality Objectives (IPWQO) of 5 ug/L during both the August and November sampling at BM-4 and during the August sampling at station BM-6.

4.2   Sediment

While sediment sampling during this study was undertaken to a depth of 30 cm in most locations, there is no certainty as to the actual period in time to which this sediment profile corresponds. Vanderpost (1972) estimated sediment

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accumulation in Lake Ontario to be up to 2 mm/year, while Durham and Oliver (1983) estimated sedimentation rate at the western end of Lake Ontario to be up to 3 mm/year. Mudroch and Capobianco (1980) calculated the sedimentation rate in Moira Lake, a small Shield lake also located downstream of a mining area, as 2.36 mm/year. Cornett *et al.*(1992) estimated that accumulation rates in Moira Lake ranged between 1.5 mm/yr and 3.2 mm/yr. Cook and Johnson (1974) estimated a rate of up to 5 mm per year in the Bay of Quinte. Given these estimates, a sedimentation rate of 2 to 3mm/year would not be unreasonable in lakes in the Bancroft area. Based on an estimate of 3 mm/year (assuming a constant sedimentation rate), sediments in the 0-10 cm section would correspond approximately with the period from 1967-1999, in the 10-20 cm section with the period from 1934 to 1967, and in the 20-30 cm section from 1901 to1934 (it should be emphasized that these dates are only estimates). Since mining activities began in this area around the mid-1950's, these estimates suggest that sampling in most locations occurred down to sediment strata that pre-date mining activities.

It should be noted that the above estimates apply only to the lakes in the system. The dynamic nature of stream environments, particularly their susceptibility to periodic erosion events that can mobilize substantial quantities of sediment (typically caused by unusually high rainfall or snowmelt conditions), precludes the estimation of reasonably reliable sedimentation rates in streams.

Madawaska Mine

The results of the sediment sampling indicate that loss of uranium from the site has occurred to both Bentley Lake and Bow Lake. Both lakes had sediment concentrations of uranium that ranged well above levels in background lakes (Figure 21). Measured concentrations of uranium exceeded the Saskatchewan Severe Effect Level (SEL) of 21ppm (Kurias *et al.*, 2000) from all of the mine sites, with the exception of site MM-10. Bentley Lake sediments, while lower in uranium than sediments at the east end of Bow Lake, generally had higher concentrations in the surface sediments as compared to the subsurface. This pattern suggests that accumulation of uranium in Bentley Lake sediments is of more recent origin, and, as indicated by the elevated levels in the water column, is likely on-going. Sediment concentrations were also higher closer to the mine site (station MM-2), than in the north basin of the lake (station MM-1).

While sediment concentrations were lower in Bentley Creek near the discharge from Bentley Lake (station MM-3), surficial sediment concentrations just upstream from Bow Lake (station MM-4) were approximately 5 times higher, and suggest that the tailings area adjacent to the creek may be a source of uranium to Bentley Creek. The high concentrations in the surface sediments (153 ppm) as compared to the subsurface (121 ppm), suggests that here as well, the losses are on-going. This is further supported by the water quality results, which show elevated levels at station MM-4 compared to MM-3. The historical data from the PWQMN also indicate that these losses have been continuing for many years, though concentrations in the water column in more recent years has been much lower than in the 1970's (Figure 15).

The surficial sediment concentrations at the east end of Bow Lake (station MM-5) were similar to surficial concentrations in Bentley Lake (station MM-2)(both were at 239 ppm), but subsurface concentrations were much higher, ranging up to 462 ppm in the 10-20 cm section; which was the only location where concentrations exceeded the SEL of 390µg/g developed for lakes in Saskatchewan (Kurias *et al*, 2000). This section would correspond roughly with the time period 1934-1967, and would encompass the initial period of operation from the mid-1950's to 1964. The bottom section (20-30 cm) also showed elevated levels compared to concentrations in background lakes, and there are number of possible explanations for these higher concentrations. It is possible that even before mining activities commenced, there may have been some accumulation of uranium in Bentley Lake sediments, likely from natural weathering of rock in this area. Alternatively, there may have been periods where significant sediment mixing has occurred, which could have integrated surface material into the subsurface. Finally, the estimate of time period for each section is based on values derived from other areas. Sediment accumulation rates may have been greater than the 3mm/year estimated, and therefore the time period defined by each 10 cm section would be much shorter. For example, if sediment accumulated at a rate of 5 mm/year, the time period defined by each section would be 20 years, and the bottom section would correspond to the time period 1940-1960, which would include the early years of mining activity.

While the influence of external sources via Bentley Creek have already been noted, the reservoir of contaminated sediments in Bow Lake and Bentley Lake could also act as a source of metals contamination to the water column and be a significant factor in the re-mobilization of metals from the sediments. While the data suggest that the deepest part of the eastern basin of Bow Lake is permanently stratified due to high metals concentrations (while oxygen measurements were not taken the presence of black sediment, characteristic of the presence of iron sulfides, and the high conductivity strongly suggest anoxia during the period of sampling), there are other areas of the lake that would be subject to periodic changes in redox as the chemocline rises in the summer months. During this period, shallower areas around the periphery of the deeper basins would go anoxic, with resultant changes in metals release. As such, parts of the deep basin of Bow Lake, and also the deeper parts of Bentley Lake (under the summer thermocline/ chemocline) would experience periodic redox changes during lake turnover, with resultant metals release at each phase.

A number of potential routes could contribute uranium to Bow Lake and would include losses via overland flow from the mine site that could carry both dissolved metals and those attached to particulates, seepage directly to the lake through groundwater movement, and both dissolved and particulate-bound uranium carried in via Bentley Creek.

While the elevated levels of metals in surface sediments of both Bow Lake and Bentley Lake may suggest ongoing losses, these elevated levels are also likely related to the mine reopening in the 1970's.

The elevated levels of uranium at other stations in Bow Lake (stations MM-6 and to a lesser degree, MM-7) show that contamination has spread out across the lake. Since particulate-bound metals would be expected to settle to the sediments close to the source, a fate that would be aided by the presence of the sill separating the east basin from the rest of Bow Lake, the broad distribution suggests that at least part of the losses in the past have been through dissolved metals, either through losses from the site or reflux from the sediments, that have combined with particles and settled out over time. The higher levels in the small lakes further downstream (stations MM-8 and MM-9), suggest this as the primary mechanism by which uranium has been distributed away from the site (though the possibility of some resuspension and downstream transport of fine particulates from Bow Lake sediments cannot be discounted).

The low levels downstream in Bentley Creek (station MM-10) suggest that these lakes have trapped most of the metals, and what has not been held back by these lakes has likely been carried far downstream (the Crowe River system) and diluted to the point where it is no longer detectable.

The small lake at MM-9 has clearly been trapping suspended/dissolved metals for some time, given the depth of contamination. Concentrations in both the surface and subsurface sediment of this lake were higher than either the next upstream lake (station MM-8) or the west end of Bow Lake (station MM-7), and suggest that there has been considerable downstream transport, either in the dissolved state, or bound to fine particulates (i.e., those that could remain suspended in the water column).

Other metals

The increases in uranium concentrations noted in sediments of Bentley Lake and Bow Lake are paralleled by increases in manganese and strontium. As noted for uranium in Bentley Lake, the surface layers yielded the highest concentrations of these metals, and similarly suggest that most of the accumulation has occurred in the last 20-30 years. All four metals also increased at station MM-4 as compared to MM-3 and suggest that losses of these metals is occurring to Bentley Creek adjacent to the mine site.

Sediment at the east end of Bow Lake (MM-5) again showed that the middle layer (10-20 cm section) was the highest for strontium, while surface sediments had the highest concentrations of manganese and iron. The data suggest that losses of manganese and iron have been higher since the initial shutdown of the plant in 1964 (and are still on-going as indicated by the water quality data), while strontium seems to coincide with the period of initial operation. There are 2 possible reasons for the higher manganese and iron concentrations in the 0-10 cm section: more manganese and iron were released during the period when the plant reopened in the 1970's,or, there has been a greater loss of manganese and iron after the

plant closed due to surface runoff or leaching. However, the high levels of iron and manganese in the sediments would also serve to limit the availability of other metals such as U and strontium since iron and manganese hydroxides have been identified as the major scavengers of other metals under oxic conditions, and would bind many of these metals. This may also account for the lack of effects in sediment bioassay testing at station MM-5, despite the elevated levels of both uranium and radium-226.

The indication that anoxic conditions occur periodically (i.e., the high conductivity in the bottom water) suggests that at certain times, there may be releases of metals as redox conditions change from oxic to anoxic, and may partially account fo the elevated concentrations of some metals in the bottom water. While leaching of manganese from adjacent surface areas is likely an ongoing process, release of manganese and iron as conditions at the bottom become anoxic would also contribute to higher concentrations in the bottom water. However, the relatively low concentrations of manganese in sediments at station MM-5 would be unlikely to fuel the entire increase in manganese that has been observed during the 3 sampling periods, which strongly suggests there has to be outside source(s) of manganese to the system.

It is noteworthy that water concentrations of manganese in August at station MM-5 increased 940 times over levels at background stations, but increased in sediments only 3-times over background. The bottom water concentration of manganese was 11.3 ppm, while sediment concentration was 1100 ppm, and while the increase in bottom water concentrations could be due to release from sediments as conditions become anoxic, the concentration of manganese in bottom water in Bentley Lake (station MM-2) was much lower, despite higher sediment concentrations at this station (1800 ppm vs. 1300 at station MM-5). Therefore, while sediment manganese may be released to the water column at certain times of the year, this does not appear to be the major source of manganese to the bottom water.

Radionuclides

Concentrations of radium-226 in sediments were highest in Bow Lake (station MM-5), and unlike most of the other metals (including U-238), were highest in the surficial sediment layer (Figure 25). This pattern suggests that the bulk of the accumulation has occurred primarily in the last 30 years, though levels in the 10-20 cm section suggest there was significant contribution during the first years of the mill operation. Levels in Bentley Lake were relatively low, and this area does not appear to have been a major repository of radionuclides from the site. Most of the material appears to have traveled down to Bow lake either through discharge to Bentley Creek, or through seepage or overland runoff from the site.

Sediment concentrations of radium-226 at many of the sites in Bow Lake exceeded the Saskatchewan sediment SEL (0.6 Bq/g), and levels increased 400 times over background at station MM-5, water concentrations at the bottom increased only 12 times over background. These results further suggest that the anoxic conditions in the bottom of the eastern basin, as indicated by the conductivity and metals concentration changes with depth, are not temporary, but permanent. The formation of stable metal-sulfide complexes would not be expected to favour the release of significant quantities of metals from the sediments.

While sediment concentrations of uranium increased 18 times over background, water concentrations in August increased 196-fold over background. While some of this could be due to release from sediment during dissolution of manganese/iron hydroxides and metal-sulfides during redox changes, it is likely that other sources, such as Bentley Creek, and seepage and overland flow from the mine site have also contributed to elevated levels in the sediments. The PWQMN data show that there is continual input of uranium and other metals occurring between the upstream and downstream locations along Bentley Creek that would serve to feed and perpetuate this cycling.

Dyno Mine

Field observations indicate that a substantial amount of tailings have been deposited in Farrel Lake, particularly off the

mouth of Farrel Creek. The deposition of tailings material in this area appears to be significant. While the core penetrated to 40 cm, the upper 20 cm of the core appears to be comprised primarily of tailings (Table 1), while the deeper section appeared to be a mix of tailings material and clay. This would account for the high concentrations of radioactive elements (Ra-226 and U-238) and uranium in these samples.

Elevated levels of the metals of concern (iron, manganese, strontium and uranium) and radionuclides were also noted in the 0-10 cm section at station DM-3, in the deep basin of Farrel Lake, with concentrations of manganese, uranium, cadmium and copper exceeding the Provincial Sediment Quality Guidelines (PSQG) Lower Effect Level (LEL) and the PSQG SEL for iron at these sites. Concentrations of iron, manganese and strontium were higher here than at station DM-2. The pattern of distribution suggests that those elements present in the tailings (U and Ra) and likely entering the lake bound to tailings are not as mobile as those that would likely be entering the lake via seepage or leaching (Fe, manganese and strontium). A slight elevation of metals concentrations in bottom waters of the deep basin (station DM-3) during May and a much more pronounced increase in August (particularly in manganese concentration), suggest that the deep basin does undergo periods of low oxygen conditions (this is further suggested by the increase in conductivity in the bottom waters, and the black colour of the sediments, which is characteristic of the presence of iron sulfides- iron concentrations were very high in these sediments). During these periods, there could be release of metals from the sediment to the overlying water as those metals complexes that are redox sensitive respond to the changing conditions.

The elevated levels of uranium and lead exceeded the LELs (21ppm and 31ppm respectively) in the sediments of the beaver pond adjacent to Farrel Lake (DM-4) show that some of the metals have been transported out of Farrel Lake. Two mechanisms could account for this. Both dissolved and complexed metals could be transported from the tailings area via the upper end of Farrel Creek to Farrel Lake. These could either stay in suspension, to be carried out of the lake and into the adjacent beaver pond or, they could form precipitates and settle to the sediments, to be physically re-suspended during turnover or during periods of high wind/wave action and transported out, or they could be released from the sediments during periods of low oxygen conditions in the bottom water.

The relatively high surface concentrations of uranium in the pond sediments suggest input from external sources, such as Farrel Lake, is an on-going process. Concentrations in the pond were higher than in sediment at DM-2 that had visibly high concentrations of tailings material, and the pond appears to be a sink for many of the metals of concern, since levels in sediment at downstream stations were typically much lower. The small area of the beaver pond, and hence its relative quiescence could serve to reduce the potential for sediment re-suspension. In addition, the shallow water depth (<1 m) would serve to prevent the formation of anoxic conditions at the sediment-water interface that would favour the release of metals from sediments. Data for radionuclides suggest most is being held in sediments of Farrel Lake, since levels in the beaver pond were much lower. This may suggest that the elevated levels of uranium in the beaver pond sediments are primarily due to dissolved and suspended forms of U in the water column, discharged from Farrel Lake, rather than release from sediments.

In fact, for uranium, the highest sediment concentrations were recorded at station DM-4 (beaver pond) with subsurface concentrations (290 ppm) higher than surface (212 ppm).

The rapid decline in sediment metals indicates a relatively low amount has moved down Farrel Creek to Eels Lake. While levels in Eels lake for uranium were at or below background levels, Ra-226 levels exceed the Saskatchewan sediment SEL in Farrel Lake and at the sites immediately down stream of the lake, which suggests there may have been some loss and transport to Eels Lake. Concentrations of all other metals in Eels Lake sediments were similar to background levels (arsenic levels in sediment, as well as a number of other metals increase substantially in the southern end of Eels Lake, but these appear to be unrelated to the Dyno Mine site).

Despite increases in manganese in bottom water, there was little change in sediment concentrations of manganese as compared to controls or downstream stations. The higher concentrations of some metals in the southern end of Eels Lake suggest a source other than the Dyno Mine site.

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Bicroft Mine

Background concentrations of most metals were lower in Centre Lake than any of the other two background locations.

Sediment uranium, radium-226 and manganese increased slightly at BM-1, adjacent to the tailings dam at the north end of Auger Lake. The presence of higher concentrations in the sediments suggests there has been some movement (possibly seepage) from the tailings areas to Centre Lake. Since the increase is most apparent in the 0-10 cm section, and secondarily in the 10-20 cm section, this appears to coincide with the period of operation of this site. Early maps of the area show a small creek from the tailings area to the south west end of Centre Lake (the tailings area did not appear to reach Hwy 121), some of this may be due to losses prior to filling of the containment area. However, the higher surface concentrations suggest most of the loss has been in the last 30 years or so, which would have been after the site was closed. Levels of radium-226 and uranium exceed the SEL and LEL (respectively) at this site.

While station BM-2 was in the tailings disposal area and therefore was not of direct concern to this study, the concentrations of uranium and radium-226 do provide a useful reference point. In particular, the results show that sediments at some locations not on the mine sites had higher sediment concentrations of radium-226 and uranium than did the tailings themselves.

While sediments below the Pond A discharge (station BM-4) were elevated in uranium (exceed the LEL), radium-226 and manganese (exceed SELs), the most significant increases in uranium were observed at the mouth of Deer Creek at Inlet Bay (station BM-6) and in Inlet Bay itself (BM-7). Uranium concentrations at the mouth of Deer Creek were 346 ppm and in Inlet Bay, up to 134 ppm in surficial sediments. Radium-226 was highest at BM-7 in Inlet Bay. By comparison, uranium concentrations in the tailings area ranged up to 63 ppm, while radium-226 concentrations were similar to levels in Inlet Bay (i.e., 14 Bq/g at both sampling sites). Both sediment sampling, and water quality data clearly indicate that there has been loss of uranium and radium-226 from the site and that these have accumulated in the sediments of Deer Creek, as well as in the deeper basin sediments of Inlet Bay. The sediment record indicates that the increase in uranium and radium-226 concentrations in Inlet Bay coincides with the startup and operation of the Bicroft Mine in the mid- 1950's. Water quality data show that the site still contributes uranium and radium-226 to Inlet Bay.

Unlike other sites, which had bodies of water adjacent to the mine sites, or immediately downstream, the first significant depositional area below the Bicroft site is Inlet Bay. Inlet Bay itself is a deep basin more or less cut off from the rest of Paudash Lake by a narrow passage at the south end of the lake. As such, there would be little potential for movement of sediment out of Inlet Bay. The distribution of uranium and radium-226 at other station in Paudash Lake however, does indicate that some metal transport out of Inlet Bay has occurred, likely as dissolved metals. For example, concentrations of uranium and Ra-226 in surficial sediments in Lower Paudash Lake (stations BM-10 and BM-11) are higher than background and also higher than in subsurface sediments, and suggest a relatively recent dispersal of uranium and radium-226.

Bottom water concentrations of metals (principally manganese, iron and uranium), as well as the conductivity profiling conducted in Inlet Bay suggests that the sediments are not a significant source of metals back to the water column. The data suggest that Inlet Bay does not experience the same conditions of anoxia (while a definite thermocline existed at station BM-7 in August, conductivities remained unchanged from the surface to the bottom), and as such, the conditions would not be favourable for significant release of metals form sediments. The sediment and water data suggest that while sediments are a reservoir for metals, and in particular uranium and radium-226 (which exceeds the sediment SELs at some sites, Table 4), they are currently acting as a sink with little release back to the water column. Since the size of Inlet Bay is much larger than the eastern basin of Bow Lake, there is considerably more potential for complete mixing of the water column (i.e., greater fetch) during spring and fall turnover, than in the small confined eastern basin of Bow Lake. The process described for precipitation of metals in Bow Lake sediments would also by applicable to Inlet Bay. Metals entering the Bay as free ions would tend to co-precipitate with iron and manganese oxides/hydroxides, as these form in the water column. The scavenged metals would be deposited in the sediment, and over time would be buried by new material. With stable bottom conditions (i.e., no seasonal changes in redox) the metals - complexes would tend to be stable, with little release of free ions at the sediment-water interface.

4.3 Benthic Community Structure

While laboratory sediment bioassays can be useful in assessing the impacts of contaminants in sediment on benthic organisms, these suffer from a number of limitations. In particular, sediment bioassays alter the natural characteristics of the sediment, which can result in enhanced release of some contaminants under the test conditions. Benthic community analysis can be valuable in overcoming some of these limitations, in particular in determining if there are impacts on benthic organisms under natural, undisturbed conditions. For practical purposes, benthic community analysis can be considered as a long-term in-situ bioassay that considers chronic effects endpoints. Those factors that can affect benthic organism distributions over many generations (i.e., sublethal effects) would, over the long term, result in the gradual reduction and eventual elimination of the susceptible groups. As such, long-term toxic effects can often be inferred from the presence of some species, or more significantly, the absence of other species that are typically present in similar habitats in unimpacted areas.

However, benthic community assessment suffers from its own limitations. Since benthic organisms can be affected by both the water column and the sediment environment, it is often difficult to determine the causative agent. As well, where a number of compounds co-occur in sediment or water, it is not possible to attribute a response in the benthic community to any one contaminant (i.e., it is very difficult to determine specific cause-effect relationships). Finally, while the response of benthic communities to severe contamination is usually readily apparent, lower levels of contamination may result in more subtle effects. Since the habitat characteristics, such as particle size, water depth, temperature, oxygen concentrations, as well as a number of other variables, can also affect benthic organism distribution, it is often difficult to separate out the subtle effects of low levels of contaminants from those of natural habitat characteristics. Thus, while benthic community analysis can often determine that an effect is present, it cannot readily quantify this effect, and also cannot determine specific cause-effect relationships between benthic organisms and contaminant concentrations.

Benthic communities in the background lakes (Siddon Lake, station MM-LC; Centre Lake, station BM-LC and Brough Lake, station DM-LC) are typical of those in deep, oligotrophic shield lakes. Saether (1975) noted that a number of chironomid species typically comprised the communities of various types of lakes, from oligotrophic to eutrophic, and developed a typology of lakes based on these communities. The background lakes in this study typically fit the *Tanytarsus-Stictochironomus*-type lakes, which were characterized by Saether (1975) as moderately oligotrophic to mesotrophic.

Madawaska Mine

Siddon Lake (station MM-LC), the background lake for this site, based on its chironomid fauna fits into the above noted lake classification. *Tanytarsus* and secondarily, *Stictochironomus*, comprised the largest component of the chironomid fauna, though both *Chironomus* and *Procladius* were also present and suggest this lake is oligotrophic-mesotrophic. A sizable oligochaete community also existed within Siddon Lake, characterized by the presence of *Limnodrilus hoffmeisteri*.

Bentley Lake (stations MM-1 and MM-2) differed from the control in the absence of the oligochaete community and the reduction of the chironomid community to those species known to be tolerant of low oxygen concentrations (i.e., *Chironomus* and *Tanypus*). While the reduction of the chironomid community can be explained by low oxygen levels in the sediment, the absence of the oligochaete community cannot. Most oligochaetes common in deeper lakes, and in particular, those also found in organically enriched areas, such as *L. hoffmeisteri*, can often withstand prolonged periods of low oxygen. If oxygen reduction were the only effect in these lakes, a reduction or elimination of the oligochaete community would not be expected. The absence of oligochaetes therefore, suggests that there may be other factors, such as contaminant effects. However, correlation analysis of benthic taxa with water and sediment chemical parameters did not yield any significant correlations for any of the benthic groups, and suggests that contaminant effects, if present, are too subtle to be clearly delineated.

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Despite a slight reduction in benthic diversity at station MM-4, the benthic fauna at this station showed little change from that at MM-3, and suggests that the higher metals levels noted in the runoff in earlier sections of this report are not having a measurable impact on the benthic community.

The benthic community at station MM-5, in the east basin of Bow Lake, was similar to those in Bentley Lake and suggest similar impacts, namely, low oxygen concentrations which have reduced the chironomid fauna to one of a few species tolerant of these conditions. As in Bentley Lake, the reduction of the oligochaete community, which would not be particularly susceptible to low oxygen levels, suggests there may be an impact from sediment metals on these organisms, but again, the effect cannot be attributed to any specific metals in either the sediments or bottom water. While oligochaetes are typically considered as organisms tolerant of "pollution", they are often more susceptible to the effects of contaminants than some of the other benthic organisms due to their feeding habits. Since oligochaetes feed by ingesting sediment, they are often directly exposed to contaminants in sediment. As such, they may suffer adverse effects before other organisms that feed above the sediment surface, such as mayflies.

While the chironomid communities at stations MM-6 and MM-7 , in the central and western sections of Bow Lake had reductions in density and diversity similar to the changes noted at station MM-5, the oligochaete community, particularly at station MM-6, appeared to have recovered. The presence of the oligochaete community suggests that other areas of Bow Lake would support similar communities, and suggests the severe reduction at station MM-5 is likely due to outside influences and not natural conditions within the lake. The appearance of the sphaeriid community at both stations MM-6 and MM-7 further suggests that the absence of this community at station MM-5 could also be related to conditions in the water or sediment.

While the absence of oligochaetes at station MM-8 may suggest impacts in this small lake as well, the presence of mayflies (*Caenis*), and the sphaeriid clams, indicates a high level of organic matter, and possible oxygen stress. However, concentrations of a number of metals remained high at this station, and the reduction in the benthic community, and in particular the oligochaete community, may be related to contaminant concentrations in the sediments, though there is no strong evidence of this.

The more diverse benthic community at station MM-9, and in particular, the presence of a number of groups absent upstream, suggests there are no detectable impacts on the benthic community at this location. However, contaminant concentrations were as high or higher at this station than at station MM-8, and suggest that the reduced benthic community at MM-8 is not related to sediment contaminants.

Samples from downstream communities (stations MM-10 and MM-12) consisted of diverse benthic communities, comprised of a variety of organisms typical of both flowing and standing waters (both sites, while in flowing water, were actually sampled in relatively quiescent pools). There were no detectable changes in the benthic communities at either of these stations, and no apparent impacts that could be attributed to contaminant concentrations.

Dyno Mine

As noted above, the background lake for this site (Brough Lake, station DM-LC) was typical of the oligotrophic/ mesotrophic lakes in this area. The fauna was restricted primarily to the chironomid community, which was strongly represented by the genera *Stictochironomus* and *Tanytarsus*.

Station DM-1 was similar to the stream control and suggests no impacts from the mine site in this area.

The fauna at station DM-2, in the north end of Farrel Lake, was also relatively diverse, particularly in term of the variety of chironomid species, as well as the presence of a number of insect species (the most notable of which was the burrowing mayfly *Hexagenia*), as well as oligochaetes and sphaeriids. Therefore, despite the presence of tailings material in the sediments, and the elevated metals concentrations in the sediments, there is no apparent effect on the benthic community.

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The severe reduction in the benthic community at station DM-3, and the dominance of the chaoborids suggests both periods of reduced oxygen, as well as potential contaminant effects. Chaoborids are not true benthic organisms, but rather are water column inhabitants. Since they can drift vertically in the water column (usually on a diurnal basis), they can avoid unfavourable environments, such as anoxic waters. Their presence, and the reduction of the benthic fauna to a few species of chironomids known to be able to tolerate low oxygen concentrations, suggests that the primary impact on the benthic community at this site is oxygen depletion at the bottom. The dramatic change in the benthic community due to low oxygen levels, however, would mask any contaminant effects, and the presence of at least a few species of chironomids suggests that the sediments are not toxic. However, the absence of the oligochaete community again suggests that additional effects, due to elevated metals levels in the sediments or bottom waters, may also be present.

However, the low diversity of organisms at station DM-4, is not as readily interpreted. While this was a relatively shallow pond, the reduction of the benthic community to primarily the chironomid community suggests there may be other factors. Other, similar ponds within the study area had much more diverse faunas, and suggests that either contaminant effects (many metals were higher in this pond than in Farrel Lake), or, the physical characteristics of the pond are limiting the benthic community. Since levels of most contaminants were lower in the sediments than at some of the other sites where no direct impacts could be detected, the high organic matter content of these sediments may itself be limiting. This may result in an oxygen stress within the sediments, that would limit the fauna to those species able to withstand lower oxygen levels, such as the oligochaetes and chironomids that were present.

The pond at station DM-5, as well as station DM-6 were both in slowly flowing waters, and thus, in a different type of habitat to the beaver pond at station DM-4. Both these sites had much more diverse benthic communities that included a number of insect species as well. The high density and diversity suggest there are no effects that could be attributed to the mine site.

Station DM-8 was located in the north end of Eels Lake, near the mouth of Farrel Creek in relatively shallow water. This is also reflected in the diversity of organisms at this location, and density of organisms was among the highest at any of the lake stations sampled. The benthic community here appears to be unaffected by any contaminants from the mine site.

The remainder of the stations in Eels Lake were similar to unaffected lakes within the study area in terms of benthic communities present and suggest that there is no impact on benthic organisms in Eels Lake that could be attributed to the mine site.

Bicroft Mine

Centre Lake, the background lake for the Bicroft Mine site was one of the deepest basins sampled. The benthic community in this lake, as noted earlier was comprised of the chironomid community that is typical of oligotrophic/ mesotrophic conditions.

A similar community was observed in the southwest basin (station BM-1) adjacent to the north tailings dam, and suggests the slight increase in sediment concentrations of some of the metals associated with the mine site are not having an observable impact on the benthic community.

The samples collected within the tailings pond (station BM-2) are not directly the subject of this study, since this area is directly on the property. However, the results do demonstrate that, while there may be some effect from the tailings, namely in the reduced diversity of organisms, the effect is not severe. Since the toxic effects of metals is related primarily to their availability, the lack of a pronounced toxic effect (the reduced diversity could suggest the presence of a subtle toxic effect, to the most sensitive organisms) suggests that the availability of metals from the tailings themselves is relatively low.

The discharge from Pond A appears to have had a minor effect on the benthic community downstream in this tributary (station BM-4). In comparison to station BM-3, the stream control for this site, there was a reduction in both density and

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diversity of organisms. In particular, the more sensitive components of the benthic community, such as the mayflies and caddisflies, that were present at BM-3 were notably absent at BM-4. Similarly, the chironomid community at station BM-4 was much less diverse. While there is no direct correlation with benthic organism density or diversity (as a whole or among individual groups) and contaminant concentration in either water or sediment, the reduction in these groups does suggest a subtle response to the higher levels of some contaminants.

A similar effect is also suggested at station BM-6, where, even though diversity was high, density of organisms was less than 50% the total density at station BM-3. Winner *et al* (1980), found in streams affected by elevated metals concentrations that the effects on the benthic community often resulted in an overall reduction in the fauna. Since sediment bioassay testing found the highest tissue residues in fish from sediments at station BM-6, the availability of metals from these sediments appears to be higher than at any of the other sites. Therefore, while sediment concentrations of many of the metals were not the highest recorded, the data suggest they may be more biologically available (likely as consequence of the higher sand content of these sediments).

The elevated levels of some metals in sediments of Inlet Bay may also be having an effect on the benthic community of this basin. The presence of high density of chaoborids, coupled with the low density of other organisms, and the chironomid community that was reduced to those species tolerant of reduced oxygen levels, all suggest that the primary factor affecting the benthos is periods of low oxygen in the bottom waters. However, the absence of the sphaeriid community, and the marked reduction of the oligochaete community are similar to changes noted in Bentley Lake and Bow Lake, and suggest there may be some effects on the benthic community due to other factors, rather than just low oxygen levels, since both of these groups are able to tolerate such conditions. Reduced oxygen levels could mask any effects due to contaminant concentrations, though the lack of biological effects in the sediment bioassay testing, at much higher sediment metals concentrations than were observed at this site, suggests there would be little additional impact on the benthic community at this site due to sediment contaminants.

The other sites in Paudash Lake yielded faunas typical of the deeper profundal areas of oligotrophic/ mesotrophic shield lakes, and there is no suggestion of impacts due to contaminants form the mine site.

4.4   *Sediment Bioassay Testing*

The results of the sediment bioassay testing indicate that there is little direct toxicity associated with sediment contaminants, though toxicity was observed among some of the test species at some of the sites. Only sediments from station DM-3, in the deep basin of Farrel Lake resulted in a significant increase in mortality among the mayflies and fathead minnows (chironomid mortality at this station was low). Sediments from station BM-6 resulted in mortality to mayflies only, but also resulted in much higher tissue residues in fathead minnows that at any of the other stations. Sediments from station MM-5 in Bow Lake resulted in increased mortality among the mayflies over what was observed in the BM-LC reference (Centre Lake) sediments, but the difference was not statistically significant.

Station MM-2 sediment resulted in no increase in mortality in any of the assays, and in fact, mortality among the mayflies and fathead minnows was less than in the reference sediment from Centre Lake (station BM-LC). In addition, both mayfly and chironomid growth was higher than in the control reference sediment or the control sediment from Honey Harbour. Both organisms grew better in these sediments than in any of the other sediments tested. Fathead minnow tissue residues at the end of the 21-day test do show uptake of uranium to a level nearly 14-times higher than in the reference sediment. The calculated Biota-Sediment Accumulation Factors (BSAF) showed no difference in the relative uptake of uranium compared to the reference sediment, even though absolute concentrations were high in fish exposed to MM-2 sediments. Therefore, the data suggest that despite a low BSAF in these sediments, the total concentration of uranium (and possibly also Ra-226, which was not analyzed for due to lack of sufficient sample) is higher in fish exposed to sediments with higher concentrations. This has implications for adult fish or fish at higher trophic levels, and will be addressed in follow-up studies in 2002 to measure levels of radionuclides and metals in sport fish.

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It should be noted that sediment bioassay test procedures can result in higher release of metals from sediments than might be observed under natural conditions. Since the sediment is removed, sieved, and mixed with water, the existing redox conditions (typically an oxic layer of 2-3 cm overlying an anoxic deeper layer) are completely altered. The change from anoxic to oxic can result in dissolution of metal-sulfide complexes in the sediments, with resultant release of any co-precipitated metals. As such, the test conditions most closely simulate what might occur under natural conditions, were the sediments to be re-suspended in the water column and deposited elsewhere. While these test conditions may not be directly applicable to sediments deposited in deeper basins of lakes, where events capable of disturbing these sediments seldom occur, they are relevant to what may be expected to occur in flowing water, where areas of fine sediment deposition may be eroded during periods of high discharge.

The slight increase in mortality at station MM-5 in the mayfly assay is not significantly different (statistically) from mortality at the control station, and may be due to a combination of factors, such as metals concentrations, pH changes or the type of organic matter. The slight increase in un-ionized ammonia during the test may also be a factor, since levels exceeded the PWQO. The lack of pronounced mortality among all three test organisms at this location is interesting, since sediment concentrations of uranium (and Ra-226 in the sediment cores) were highest at this station and suggest that despite high sediment concentrations, availability of metals was limited. The decrease in pH at this location in the fathead minnow assay is likely due to release of sulfides from the sediment. Since a pH decrease was also noted in the control sediment, this suggests that the change is due to natural sources, likely a consequence of the type of organic matter (i.e., could be due to methane fermentation resulting in the release of organic acids, or the sediment could be high in sphagnum (peat), and/or sulfate-reducing bacteria, both of which can result in increased generation of sulfides, which can result, under oxidizing conditions, in the generation of SO_4). The decreased pH at station MM-7 in the mayfly assay could be due to similar changes in the sediment as a result of changes in redox in the test conditions.

Uranium tissue residues in fathead minnows were approximately an order of magnitude higher than in the reference sediments, and suggest that some uranium was released from the sediments during the test period. Again, while BSAFs were similar to the reference sediment, the higher concentrations of uranium in these sediments resulted in higher tissue residues in the minnows.

Sediment from MM-7 resulted in no mortality relative to reference sediments in either the mayfly or the chironomids. While mortality of fathead minnows was higher than the reference sediment, this was due to failure of the aeration equipment on Day 19 of the test in one of the test chambers and all fish mortality occurred in this test chamber. Therefore, mortality was due external factors (lack of oxygen) and not to conditions within the sediment. Tissue residues in minnows from the remaining test chambers were similar to concentrations in minnows in sediment from MM-2 and MM-5, and again suggest availability of metals from sediment under the test conditions.

While sediments from station MM-9 showed no mortality in any of the test species, minnow tissue residues were higher than at any of the upstream sites (approximately 2-times levels at station MM-5 and MM-7). Since sediment concentrations were lower than in the upstream test sediments (181 µg/g vs. 540 µg/g in MM-5 sediments and 474µg/g in MM-7 sediments), it would suggest that metals are relatively more available from these sediments. When tissue residues are compared to levels in fish from the reference sediment tests (Table 15) levels are higher (24-times) than in fish from either MM-2 sediments (13-times background) or MM-5 sediments (12-times background).

It should be noted that concentrations of metals in sediments used in bioassay testing and those obtained by core sampler for chemical analysis usually differ. Samples for bioassay testing are typically obtained by grab sampler, which usually samples sediment to a depth of 10-15 cm. In addition, the samples are sieved to remove coarse material. Since the fine particles provide a greater surface area for metal binding, the sediment fine-particle fraction typically has the highest concentration of contaminants. Since sieving concentrates this fraction to some degree, it is not unusual for sediments used in bioassay testing to have higher concentrations of contaminants, than samples collected from the same location, at the same time, for chemical analysis. Finally, the distribution of contaminants in sediments is seldom uniform. Areas adjacent to one another can have slightly different chemical concentrations simply due to differences in fine-sediment content, or minor differences in current that can result in differential settling of particles from the water column.

Sediments from below the Dyno mine site showed a significant increase in mortality at one site, station DM-3. However, sediments from station DM-2, which contained a high percentage of tailings, had relatively low levels of metals of concern, and no impact in terms of mortality, growth effects, and relatively low tissue residues. The lack of effects may be due to the high percentage of tailings material in this sediment. Since metals would be bound in the mineral matrices, they would be expected to be relatively unavailable. Station DM-3 sediment had a much higher organic matter content, though sediment uranium concentrations, at 117 µg/g in the test sediment (which was slightly higher than the bulk sediment concentration of 89 µg/g), suggests that the observed effects are not likely due to uranium levels in sediment. Concentrations of uranium were much higher at both MM-2 and MM-5, without apparent effect on the test organisms. Sediment pH, particularly in the mayfly bioassay, decreased to a low of 3.74 by the end of the test period (21 days), and this may have had an effect on mayfly survival. Sediment pH decreased in the fathead minnow assay as well (5.2 at the end of the test). In addition, field observations noted the black colour of the sediments, which is characteristic of anoxic conditions and the formation of iron sulfides (FeS). Coupled with the high iron content in bulk sediments (100,000 µg/g or 10%), the results suggest that over the course of the test, the iron sulfide underwent dissolution, with the resultant formation of sulfuric acid and likely, hydrogen sulfide gas. Therefore, toxicity is not likely due to the presence of toxic levels of metals in the sediment, but rather, to the effects of mining activity on the deep basin of Farrel Lake, resulting in the establishment of anoxic conditions in the bottom water, which in turn enhances the formation of iron sulfides in the sediments.

Station DM-4 sediments in contrast, which yielded much higher in uranium concentrations, were collected from a beaver pond with water depth of 1m or less. As such, there is little potential for anoxia in the bottom water of these ponds. The test results show no acid generation in the test chambers, with pH remaining near neutral during the entire test. Therefore, while iron concentrations in sediment were also high at this station (57,000 ppm or 5.7%), the lack of acid generation suggests the iron was likely in the form of iron hydroxides in the surficial layers (and iron sulfides and/or organic complexes in the subsurface sediments). Fathead minnow tissue residues however, do show substantially higher uptake of uranium in these sediments (minnows could not be tested from DM-3 sediments, due to lack of surviving organisms at the end of the test period), than in Farrel Lake sediment (DM-2) or Bow Lake sediments (MM-5 and MM-7). The accumulation of uranium in minnow tissues showed an accumulation to levels 86 times higher than fish in the reference sediments, and tissue residues were 3 to 4- times higher than at any of the above stations.

Two sediments were tested from below the Bicroft Mine site: BM-6, in Deer Creek near the inflow to Paudash Lake, and BM-7 in the deep basin of Inlet Bay (Paudash Lake). While mayflies exhibited significant mortality at station BM-6 (63%), mortality among the other test species was very low, and did not differ significantly from the controls. Measurements suggest that test conditions did not vary significantly, and cannot account for the high mayfly mortality. The fathead minnow assay showed significant tissue residues at the end of the test (more than an order of magnitude above accumulation from station DM-4 sediments) that resulted in tissue residues of 39.8 µg/g of uranium, or 1323-times higher than in reference sediments (Figure 29). As such, uranium was highly available from these sediments, and this may have had an impact on the mayflies. Sediment concentrations were among the highest of the sediments tested (491 µg/g), and coupled with the high bioavailability, may have been sufficiently high to affect these organisms. Kurias *et al* (2000) developed Sediment Screening Level Concentrations (SLCs) for uranium contaminated sediments in northern Saskatchewan, with a site-specific SEL of 390 µg/g. Since availability, and hence, toxicity of contaminants is highly dependent on sediment characteristics, such as binding potential, the high availability from these sediments suggests that the observed toxicity may be due to elevated levels of contaminants, such as uranium. The relatively low TOC concentration of these sediments, coupled with the higher percentage of sand (52%) may have resulted in greater availability from these sediments, relative to the more organic sediments characteristic of the deep basins of the lakes.

The relatively low sediment concentrations of uranium appeared to elicit no response form the test organisms in BM-7 sediments. Since there was no observed bottom water anoxia observed during field sampling, this suggests there is little or no acid generation in these sediments. Accumulation of uranium from sediments was also relatively low at this station, with BSAF values similar to the reference sample.

The test results show the highest accumulation of uranium occurred in shallow-water sediments, and suggest these sediments are less effective in binding metals than the deeper lake basin sediments. However, the deeper lake basin

sediments, particularly in those basins where periods of anoxia occur in the bottom waters, appear to affect the test organisms through a decrease in pH, likely a result of increased SO_4 release as the metal-sulfide complexes oxidize.

The higher availability from shallow water sediments suggests that metal availability in these habitats is relatively high, and could be enhanced during disturbance of the sediment, such as during re-suspension of material during periods of elevated runoff. Conversely, the data suggest that lake sediments, with the exception of the deep basins of Farrel Lake and the east end of Bow Lake, effectively bind most of the metals, such that, despite high concentrations of metals, there are few effects that can be attributed directly to metal availability. It should be noted though that the high mortality in Farrel Lake sediments (DM-3) may be due to a combination of higher metals and release of sulfides, but that this cannot be determined due to the lack of tissue residue data.

The relatively lower TOC in sediments from flowing water locations may result in increased availability of metals. This in turn could have long term implications for runoff and seepage from the sites, which could result in a steady influx of bioavailable metals to the lakes. This also has implications for fish, since they could be directly exposed to these metals until they formed complexes and settled to the sediments.

4.5   *Summary*

The data collected in 2000, combined with historical data, permits an evaluation of the three mine sites in relation to the questions posed at the beginning of the investigation

1.   *What are the contaminants of concern? Previous studies have identified a number of radioactive elements that are of potential concern. Are there additional elements that may have been released during the processing of the ore that could also be of concern?*

Madawaska Mine

The data from the current study, as well as previous data from the PWQMN indicate that uranium levels downstream of the mine site are elevated over background, in both the water column and the sediments. Levels in the water column exceeded the interim PWQO of 5 ug/L for uranium during all three sampling periods in Bentley Lake and Bow Lake, and in Bentley Creek at all stations from below the outlet of Bentley Lake to the confluence with the Crowe River. None of the sites exceeded the previous PWQO of 100ug/L. The PWQO for radium-226 was not exceeded at any of the sampling sites, though levels were elevated above background and higher levels in the water column persist down to the confluence with the Crowe River.

Sediment uranium and radium-226 in the eastern end of Bow Lake were substantially higher than levels in background lakes. Though formal Ontario sediment guidelines for these elements have not been developed, "SELs" developed for use in northern Saskatchewan (390µg/g U and 0.6Bq/L Ra-226; Kurias *et al*, 2000) were exceeded at one or more sites, suggesting possible adverse effects on benthic organisms. Levels of manganese exceeded the SEL at a number of locations in Bentley Lake and Bow Lake, and strontium concentrations were substantially elevated over background.

Dyno Mine

No exceedances of the PWQOs for either uranium or radium-226 were noted, despite elevated levels of uranium and radium-226 relative to background concentrations. Sediments in Farrel Lake, as well as the adjacent beaver pond, exceeded the radium-226 criteria of 0.6Bq/g developed for Saskatchewan lakes. No exceedances of the uranium guideline for sediments developed by Kurias *et al* (2000) were noted despite concentrations in Farrel Lake sediments that were approximately 4-5 times higher than background.

Bicroft Mine

Despite elevated levels of uranium and radium-226 in Deer Creek, only uranium exceeded the PWQO at one site. There were no exceedances of the PWQO for radium-226. Levels in the water column were elevated in Deer Creek but decreased substantially in Inlet Bay (Paudash Lake). Radium-226 concentrations were high in sediments near the mouth and exceeded the criteria for Saskatchewan lakes in Deer Creek sediments. In Inlet Bay sediment uranium concentrations were elevated over background but did not exceed the SEL of 390µg/g (Kurias *et al*, 2000).

2.   *Are the sites, or any part of the sites, continuing to act as a source of any contaminants to the adjacent aquatic environment?*

Madawaska Mine

Despite the lack of exceedance of PWQOs for radium-226, the increase in water concentrations below the mine site of both uranium and radium-226 continues to contribute to the elevated levels in Bow Lake. Historical data from the PWQMN show a marked increase in uranium and radium-226 concentrations in Bentley Creek below the site, and similar results were obtained in 2000. The eastern end of Bow Lake, near the inlet of Bentley Creek, has been affected through these discharges. The small deep basin at this end of the lake appears to be permanently stratified as a result of the build up of metals, principally iron and manganese, in the bottom water. The impact of these metals has created conditions in both Bentley Lake and Bow Lake that are favourable for the release of other metals, such as uranium and radium-226, from sediments.

Dyno Mine

Elevated levels of uranium and radium-226 in the water column of Farrel Lake indicates these elements are still entering the lake. In addition, the elevated levels in sediments in Farrel Lake and the adjacent beaver pond indicates there is release and movement of these elements from the sediments.

Bicroft Mine

Higher than background levels of uranium and radium-226 below the mine site in Deer Creek show that the mine site is still a source of these elements to the system, even though levels were typically below guidelines. Elevated levels in Deer Creek sediments, and their availability to aquatic organisms, shows there is on-going movement of these metals in the system.

3.   *What is the extent and severity of any historical contamination from these sites on both water column and sediments? Is there a possibility that sediments are contaminated and could continue to act as a source in the future?*

Madawaska Mine

Sediment concentrations of uranium and radium-226 were highest in Bentley Lake and Bow Lake and elevated levels persisted downstream as far as the last small lake before the confluence with the Crowe River. Levels of uranium in Bow Lake surface sediments were up to 14 times that observed in the reference lake (background), while radium-226 concentrations exceeded the Saskatchewan SEL and exceeded the background levels by up to 405-times. Current and past data show consistently higher levels in the water column downstream of the mine site on Bentley Creek. As such there is clear indication that both uranium and radium-226 continue to enter the system from the area of the mine site. The study also found elevated levels of manganese and strontium in both the water column and sediments.

Contaminated sediments in Bentley Lake and Bow Lake appear to be a source of both uranium and radium (as well as

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manganese and strontium) to the water column. Past discharges to the system have resulted in the formation of a chemocline in the east end of Bow Lake that is currently maintained through continued inputs of these metals from the mine site, and that serves to assist internal cycling of these elements in the lake. This reflux from the sediments also serves to maintain higher concentrations in the discharge from the lake, resulting in continued downstream dispersal of these metals.

Dyno Mine

Elevated levels of uranium and radium-226 were found in the sediments of Farrel Lake and the adjacent beaver pond. There is also evidence that tailings have been transported into the lake, with extensive deposition of tailings at the north end, adjacent to the tailings dam. However, levels of these elements in the water column were low, and there is evidence of only minor reflux from the sediments. Sediment in the beaver pond had the highest levels of these elements, which suggests that materials have moved out of Farrel Lake, but have been largely trapped by beaver ponds such as this one, and the one at station DM-5. As a result, levels of these elements were low in Eels Lake sediments.

Bicroft Mine

Aside from one exceedance of the interim PWQO for uranium during the August sampling, levels of both uranium and radium-226 in the water column downstream of the site were below their respective criteria. However, sediments below the site in Deer Creek, and in Inlet Bay were elevated 58- times and 22-times levels in background lakes for uranium and up to 233 times levels in background lakes for radium-226. However, despite the elevated levels in the sediments of Inlet Bay, these appear to have a negligible impact on the water column, and suggest there is minimal released form the sediments.

The most contaminated sediments were noted in Deer Creek, and these could be transported to Inlet Bay during erosive events.

4.   *Are there any biological effects associated with elevated levels, if any, of contaminants in the water column or sediments? How severe are these effects? What is (are) the source(s)?*

Madawaska Mine

Sediment bioassay testing indicated the possibility of some toxicity at station MM-5, primarily in the reduced growth rates of benthic organisms. Since these are short term tests (i.e., less than the lifetime of the organism) the long term effects of reduced growth could have resulted, and may still result in, in the gradual elimination of susceptible groups, as their vigour and fecundity are reduced. Ultimately this could result in smaller and smaller populations. The bioassay tests also showed there was uptake of uranium from the sediments by fathead minnows, which could have implications for larger predators and ultimately, human consumers of fish.

The benthic community analysis showed there were reductions in benthic communities of Bentley Lake and Bow Lake (east basin), which suggests the presence of subtle effects on the benthic community, beyond the effects of periodic low oxygen levels. In particular, organisms tolerant of such conditions, and present at the control locations, were noticeably absent in these basins. However, the lack of correlation between benthic organisms density of diversity suggests that any effects are relatively subtle, and that these could easily be overshadowed by the pronounced effects of low oxygen levels in the bottom water. The effect appears to be limited to these basins, and downstream areas, despite elevated sediment concentrations of some of the metals did not show any detectable changes in the benthic communities relative to the control sites.

Dyno Mine

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The sediment bioassay testing showed there was direct toxicity on benthic organisms (mayflies) and fathead minnows at station DM-3 in Farrel Lake. Both the mayflies and the minnows suffered 100% mortality in station DM-3 sediments. However, since the tests cannot determine direct cause-effect relationships, it is uncertain whether the high mortality is due to the higher concentrations of some metals in these sediments, or to factors related to anoxia, that could result in the release of other compounds (e.g., H_2S) that could be toxic to the test organisms, or to a combination of the two. The lack of an effect on the chironomids, coupled with their presence in the benthic community samples, suggests that these organisms are more tolerant of these effects, while the increase toxicity could explain the absence of other organisms, including the oligochaete community in the benthic community samples.

As in Bow Lake and Bentley Lake, the tests demonstrated there is uptake of uranium at both DM-3 and DM-4, and though the rate of uptake was similar to the other sites, and the background lakes, the higher concentrations in the sediment have clearly resulted in higher tissue residues in the fathead minnows.

The reduction of the benthic community at station DM-3 in Farrel Lake shows clear signs of a community under oxygen stress. However, there are also signs that additional stressors are affecting the benthic community since some organisms tolerant of low oxygen conditions, and commonly present under such conditions, were noticeably absent. A similar situation appears to emerge for the adjacent beaver pond (DM-4) where the fauna was much less diverse than other similar ponds. These differences also suggest an impact, and it is possible that the availability of metals, such as uranium, as noted in the sediment bioassay testing, may be impacting the benthic community.

Bicroft Mine

The sediment bioassay tests showed an increase in toxicity among the mayflies at the mouth of Deer Creek (station BM-6) though the other test organisms did not show a response in increased mortality though chironomid growth rates were lower than at most of the other stations sampled. The bioassay tests also found significant uptake of uranium at BM-6, at a rate much higher than at any of the other sediments tested. The data suggest that uranium, and possibly other metals as well, are more bioavailable, and hence could be responsible for the observed mortality among the mayflies. The bioassay tests found no effect on organisms in Inlet Bay sediments.

The only indication of possible adverse effects on the benthic community was noted at stations BM-4 and BM-6. Both had reduced faunas compared to the controls, though physical characteristics were similar. The overall reduction in the benthic fauna , and not just the reduction of specific groups, is consistent with observations in the literature on the effects of metal contamination.

There were no detectable effects on the benthic communities in Paudash Lake, with the exception of Inlet Bay (BM-7). The absence of certain characteristic groups is similar to observations in Bentley Lake and Bow Lake and suggest there may be a subtle effect on these organisms, similar to changes observed in Bentley Lake and Bow Lake. However, the results of the sediment bioassay tests do not indicate any adverse effects, such as growth reduction, and the observed changes may simply be due to habitat variability or sampling artefact.

There were no effects apparent at any of the other locations in Paudash Lake.

Therefore, overall the biological effects appear to be limited primarily to those areas directly adjacent to the mine sites. While there is little direct effect on benthic communities that can unequivocally be attributed to sediment contaminants, the changes in the benthic community, and the effects on laboratory test organisms, suggest that both toxicity and bioavailability are concerns at some sites, but that the area of impact is relatively confined, and does not result in severe biological impacts that range throughout the water bodies. This is consistent with the findings of other studies in similar mining areas, that note the effects of uranium mines are confined to the immediately adjacent lakes.

5.   *Are there any long-term implications from contaminants at any of these sites? This could include a range of possible actions that may be required on the part of any potential new owner (i.e., the Crown). These actions may range from periodic environmental monitoring to full-scale sediment remediation.*

The results of the water quality component show that there is continued release of uranium and radium-226 from all three sites to adjacent water bodies. The most pronounced is from the Madawaska Mine. On-going discharge from this site, as well as internal cycling in Bow and Bentley Lakes will continue to result in exceedances of the interim PWQO for uranium. Additional concerns exist regarding other area on the Bicroft Mine site, that are currently under investigation through MNDM (R. Bradley, Pers Comm).

6.   *Recommended actions that should be undertaken before the Crown accepts title and hence responsibility for these sites.*

These are listed separately in Section 6.0.

5.0   Conclusions

1.   Only stations immediately downstream of Madawaska Mine consistently exceeded IPWQO for U. Water concentrations at the other two mine sites were below the IPWQO, except for the creek below Pond A on the Bicroft Mine site (all three sampling periods) and at the mouth of Deer Creek during the August sampling.

2.   Elevated levels of metals in the bottom waters appear to result in the formation of a more or less permanent chemocline in the south basin of Bentley Lake and the east basin of Bow Lake. Concentrations of uranium, radium-226 as well as a number of other metals such as manganese and strontium are substantially higher in the bottom waters of these lakes than in the surface waters. Data suggest that during turnover, the elevated levels in the bottom water are mixed with the surface waters, resulting in elevated levels in surface water. Data also suggest parts of these basins do not mix completely.

3.   Elevated levels of a number of metals in sediments, including iron, manganese, strontium, uranium and radium-226, occurred below all three mine sites. Iron, manganese and radium-226 exceeded the SEL guidelines in sediments below all three mine sites, while uranium exceeded the SEL only below the Madawaska mine site, and then only at depth. While guidelines are currently not available for strontium, levels in the sediment at Bentley Lake were up to four times the concentration in the sediments in the background lakes. Levels were highest in Bentley Lake and Bow Lake sediments, with LELs and SELs being exceeded for some metals in both Bentley Lake and Bow Lake. The dynamics of these two basins suggests that there is reflux of metals from the sediments to the bottom waters, particularly during periods of redox changes. As such, these sediments appear to act as a source of metals to the water column at certain times.

4.   Elevated levels of uranium and radium-226 above the LEL and SEL (respectively) in sediments at BM-7 did not result in increased concentrations in bottom water. Data suggest that Inlet Bay does not go anoxic and therefore there would be little release of these metals from sediments.

5.   Numerous studies have shown that even under stable conditions (i.e., no changes in redox or pH), there is a constant low-level flux of metals from sediments to water due to bottom water movement and equilibrium chemistry. Therefore, the contaminants in Bow Lake, Bentley Lake, Paudash Lake (Inlet Bay) and Farrel Lake sediments may contribute metals and radionuclides to the water column for many years, even if all external sources are controlled.

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6. Data from this study, as well as the PWQMN data, show a reduction in concentrations of uranium and Ra-226 in the water column since monitoring began in the 1960's. Current monitoring results show only a few exceedances of the PWQO for uranium and none for radium-226. However, these data also suggest that uranium and Ra-226 continue to enter the water column at all three mine sites at levels above background. The data also show that there are seasonal differences, with concentrations increasing in the fall months. These are likely related to rainfall and hence runoff and seepage from the sites.

7. Current data show the highest concentrations of U and Ra-226 are in Bentley Lake, Bentley Creek and Bow Lake, all of which would be influenced by the Madawaska Mine site. Concentrations of uranium exceeded the IPWQO of 5 ug/L at this site (there were no exceedances at any of the other sites on a mean annual basis (calculated over the three sampling periods) though there were individual exceedances, usually during the summer (August) sampling period. Data from the Madawaska Mine site show an increase in both Ra and U concentrations in Bentley Creek downstream of the mine site as compared to upstream at the outlet to Bentley Lake (concentrations in which are also influenced by drainage from the site to Bentley Lake), and identify the site as a source of both elements to adjacent surface waters.

8. Metals in the water column at Bentley Lake and Bow Lake are also influenced by conditions in the bottom water of these basins. Evidence exists for release of U and Ra-226 from sediments during periods of low oxygen in the bottom water. The deep basin of Farrel Lake also appears to act as a source of metals to the water column during certain periods.

9. Elevated sediment concentrations of uranium and radium-226 (as well as manganese and strontium)were noted in Bentley Lake and Bow Lake adjacent to the Madawaska Mine site. Historical water quality records (PWQMN) indicate that runoff/seepage from the sites has been a contributor. Concentrations in sediments downstream of Bow Lake were also elevated.

10. Elevated concentrations of uranium and radium-226, above LELs and SELs, were also found in Farrel Lake sediments adjacent to the Dyno Mine site, and in Paudash Lake (Inlet Bay), below the Bicroft Mine site. Concentrations of these elements in both sediments and the water column of these lakes, though elevated (in some cased up to 58 times background for radium-226 and 233 times background for uranium), were considerably lower than in Bow Lake.

11. Effects on the benthic community were primarily subtle effects that were difficult to attribute directly to elevated levels of metals in either the sediments or the water column. The deep basins of Farrel Lake, Bow Lake and Bentley Lake, as well as the background lakes, appear to undergo periods of low oxygen. This appears to have limited the fauna to those species capable of withstanding these conditions. However, the fauna of Farrel Lake, Bow Lake and Bentley Lake appear to have suffered an additional reduction in fauna that cannot be attributed to low oxygen levels and could be related to elevated levels of metals in the sediments and/or bottom waters. The benthic fauna in Deer Creek, below the Bicroft Mine site was also reduced relative to other similar habitats and may also be related to elevated metals levels.

12. Sediment bioassay testing found mortality only at two stations: the deep basin of Farrel Lake (DM-3) and in Deer Creek (BM-6). In addition, reduced growth was noted in mayflies at stations MM-5 (Bow Lake- east basin), MM-7 (Bow Lake west basin)), DM-3 (Farrel Lake), and BM-6 (Deer Creek). All locations had elevated levels of metals in both sediments and the water column.

13. Sediment bioassay testing also found accumulation of uranium from sediments in fathead minnow tissue. While the rate of uptake was similar at most stations (i.e. the amount accumulated in tissue over a defined exposure period versus the amount in sediments), the differences in sediment concentrations resulted in similar differences in tissue residues (i.e., tissue residues were higher in sediments high in uranium). The rate was considerably higher at one location (station BM-6) and suggests that uranium, and possibly other metals as well, are more available from these sediments. The increased availability from these sediments may also account for

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the increased toxicity in the bioassay tests in sediments from this location.

6.0 Recommendations

1. There is a need to further control discharges of metals and radionuclides, such as iron, manganese, uranium and radium-226, from the Madawaska Mine site. Additional monitoring at the Dyno and Bicroft mine sites is also required. Data indicate that there are elevated levels in Bentley Creek adjacent to the site. In addition, the high levels in Bow Lake (levels in the lake would be expected to be lower than in the creek, due to dilution) suggest there are other sources as well (e.g., seepage). In addition, there is evidence that reflux of metals from the sediments is also contributing to elevated levels in the water column. These represent a long-term reservoir of uranium and radium-266 that could be released to the system.

2. There is a need to determine what other sources, such as seepage, ground water movement, etc., may be contributing to elevated levels of uranium and radium-226 in Bentley Lake and Bow Lake. In particular, levels in Bow Lake suggest that sources other than Bentley Creek are contributing metals to the lake.

3. There is a need for continued monitoring of water quality downstream of the mine sites, such as has been carried out in the past through the PWQMN. The elevated levels of uranium and radium-226 below the mine sites suggests there is continuing loss of these elements from the mine sites.

4. The elevated levels in the water column of Bentley Lake and Bow Lake, as well as the biological effects noted in Farrel Lake sediments, suggests that sport fish tissue residues should be analyzed for radionuclides to ensure there are no human health concerns regarding consumption of these fish. Fish have been collected by the Ministry, including Bentley Lake, Bow Lake, Farrel Lake and Paudash Lake (Inlet Bay), and will be analysed for radionuclides.

5. There is currently evidence of significant tailings deposition in adjacent areas of Farrel Lake, downstream of the controlling structure, and data suggest that the tailings pond may be an ongoing source of contaminants into Farrel Lake. The integrity of the controlling structure should be assessed.

6. The biological effects testing, which showed limited effects on the benthic communities, both *in situ* and in laboratory testing, suggested that there is no apparent need to undertake sediment remediation at any of the sites. However, these conclusions may need to be re-evaluated should the sport fish tissue residue analysis indicate elevated levels of radionuclides in the fish tissue. The mines should also be re-evaluated in 5-10 years, to determine what improvements have resulted from any additional source control efforts.

7.0 References

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Tables

Table 1: Monthly Trend Data for Selected Metals. Provincial Water Quality Monitoring Network (PWQMN). 1970-1999.

Station	Month	Total Iron (ug/L)				Total Strontium (ug/L)				Total Uranium (ug/L)				Total Manganese (ug/L)				226Radium (Bq/L)			
		n	Minimum	Maximum	Mean	n	Minimum	Maximum	Mean	n	Minimum	Maximum	Mean	n	Minimum	Maximum	Mean	n	Minimum	Maximum	Mean
17002106402	JAN	5	170	340	252	1	490	490	490	3	2.3	8.6	4.463	2	120	230	175	5	0.01	0.111	0.044
MM-3	FEB	5	150	580	308	0				2	4.9	8.2	6.55	3	81	159	113.333	5	0.012	0.04	0.033
	MAR	10	190	600	321	1	370	370	370	5	0.79	7.6	3.578	5	40	250	123.2	7	0.009	0.074	0.04
	APR	12	20	700	182.417	2	120	820	470	6	0.1	9.3	2.908	5	15	118	52.8	15	0.005	0.063	0.031
	MAY	8	83	210	130.125	1	670	670	670	6	4.7	8.46	6.443	3	47	68	56.333	13	0.006	0.185	0.042
	JUN	15	70	1000	201	2	530	580	555	8	0.18	8.3	5.648	7	57	110	82.143	20	0.005	0.111	0.035
	JUL	14	82	300	149.286	2	530	580	555	8	3.74	7.4	6.009	6	58	170	93.667	14	0.01	0.04	0.032
	AUG	9	60	300	121.444	2	620	650	635	6	6.5	8.8	7.535	3	26	180	99.333	11	0.005	0.185	0.045
	SEP	11	50	1500	241.182	1	880	880	880	5	6.3	12	9.14	5	52	180	104.4	18	0.005	0.148	0.041
	OCT	12	56	1100	258.758	2	1010	1200	1105	4	0.1	15	10.173	6	40	470	198.667	15	0.01	0.148	0.055
	NOV	7	56	1500	295.429	0				5	9.5	20	15.966	1	328	328	328	11	0.005	0.55	0.101
	DEC	5	96	750	313.2	1	1100	1100	1100	2	4.9	18	11.45	3	150	230	200	7	0.007	0.111	0.052
17002106302	JAN	7	170	570	311.429	1	680	680	680	3	14.1	21	17.7	4	74	220	146	10	0.006	0.222	0.08
MM-4	FEB	6	200	530	335	0				2	19	20	19.5	4	95	150	122.75	8	0.03	0.185	0.064
	MAR	11	180	400	320.909	1	380	380	380	5	8.2	15	10.606	6	54	210	109	11	0.006	0.111	0.049
	APR	14	80	360	186.857	2	140	690	415	6	0.1	25	10.58	5	18	114	57.2	18	0.005	0.222	0.056
	MAY	10	130	300	191	1	620	620	620	6	11	29	18.017	5	60	130	80	14	0.005	0.185	0.075
	JUN	16	150	990	375.625	2	540	630	585	8	0.15	54	24.881	8	40	190	113.75	23	0.007	0.333	0.124
	JUL	11	120	650	316.364	2	560	600	580	7	10.24	52	32.606	4	76	107	89.75	17	0.033	0.63	0.159
	AUG	9	120	890	465.444	2	470	630	550	6	12.24	52	31.207	3	16	290	117.333	13	0.022	0.444	0.167
	SEP	11	50	680	272.727	1	670	670	670	6	7.5	50	31.917	5	68	200	116.8	19	0.018	0.481	0.195
	OCT	11	60	420	177.982	2	919	970	944.5	3	0.74	39	24.407	6	37	174	92.65	14	0.087	0.37	0.203
	NOV	8	80	1500	425.25	1	1100	1100	1100	5	17.93	48	28.186	2	57	284	170.5	13	0.008	0.88	0.154
	DEC	6	140	350	228.333	1	730	730	730	3	17	31	24.847	3	50	140	100	9	0.005	0.259	0.077
17002106202	JAN	7	40	200	132.714	1	900	900	900	3	13.2	74	34.4	4	34	330	173	10	0.022	0.222	0.106
MM-7/8	FEB	7	30	270	155.714	0				3	16	56	32	4	45	200	133.25	9	0.045	0.222	0.094
	MAR	11	140	400	219.091	1	270	270	270	5	5.67	26	17.734	6	60	166	99.667	12	0.006	0.148	0.063
	APR	14	40	450	135.143	2	62	720	391	6	0.1	53	18.367	6	16	127	57.167	17	0.022	0.296	0.085
	MAY	10	20	100	48.9	1	710	710	710	6	34	56	47.318	5	13	70	50.2	14	0.04	0.185	0.086
	JUN	16	20	150	46.875	2	580	700	640	7	0.14	61	41.12	8	20	60	37.375	22	0.048	0.185	0.111
	JUL	13	20	100	45.154	2	550	650	600	8	32.84	56.8	50.08	5	12	90	29.8	17	0.049	0.37	0.124
	AUG	10	20	140	53	2	580	630	605	7	23.5	57	49.5	3	10	230	95.333	11	0.046	0.259	0.116
	SEP	10	20	77	36.1	0				6	0.27	63	44.378	4	12	20	17.75	18	0.046	0.259	0.122
	OCT	13	20	200	60.923	2	689	690	689.5	5	0.1	63	43.714	6	24.4	150	87.4	13	0.049	0.185	0.137
	NOV	9	31	460	110.889	1	710	710	710	6	0.2	74	53.83	2	157	160	158.5	9	0.064	0.296	0.138
	DEC	6	20	100	60.833	1	720	720	720	3	42	67.26	58.42	3	20	220	120	9	0.047	1	0.208
17002105802	JAN	3	350	950	566.667					0				3	1010	1500	1203.333	4	0.148	0.741	0.324
DM-5	FEB	2	400	600	500					0				2	650	1350	1000	1	1.185	1.185	1.185
	MAR	4	300	1000	600					0				3	42	230	120.667	3	0.111	0.518	0.346
	APR	4	280	500	370					1	1.1	1.1	1.1	1	80	80	80	3	0.148	0.37	0.272
	MAY	2	260	1000	630					1	1	1	1	1	440	440	440	4	0.074	0.37	0.231
	JUN	5	400	1100	740					0				5	60	910	526	8	0.111	0.852	0.343
	JUL	5	330	950	600					0				5	230	850	594	6	0.148	1.222	0.481
	AUG	3	140	1100	480					0				1	210	210	210	5	0.148	0.481	0.281
	SEP	3	90	350	213.333					0				2	50	400	225	7	0.037	0.556	0.265
	OCT	7	100	350	229.429					2	0.7	1.3	1	3	60	200	114.333	4	0.111	0.259	0.176
	NOV	2	250	400	325					1	1.5	1.5	1.5	0				1	0.333	0.333	0.333
	DEC	2	300	400	350					0				2	40	720	380	1	0.222	0.222	0.222
17002111302	JAN	0								0								1	0.222	0.222	0.222
BM-4	FEB	0								0								0			
	MAR	0								0								0			
	APR	1	210	210	210					1	2.3	2.3	2.3					0			

Table 1: Monthly Trend Data for Selected Metals. Provincial Water Quality Monitoring Network (PWQMN). 1970-1999.

Station	Month	n	Total Iron (ug/L) Minimum	Maximum	Mean	n	Total Strontium (ug/L) Minimum	Maximum	Mean	n	Total Uranium (ug/L) Minimum	Maximum	Mean	n	Total Manganese (ug/L) Minimum	Maximum	Mean	n	226Radium (Bq/L) Minimum	Maximum	Mean
	MAY	1	360	360	360					1	1.5	1.5	1.5					0			
	JUN	2	150	350	250					2	3	10	6.5					0			
	JUL	0								0								0			
	AUG	0								0								0			
	SEP	0								0								0			
	OCT	2	330	370	350					2	0.3	18.56	9.43					1	0.222	0.222	0.222
	NOV	2	290	360	325					2	0.7	0.8	0.75					0			
	DEC	0								0								0			
17002106002	JAN	3	350	450	406.667					0				3	120	270	184	5	0.074	0.185	0.126
BM-5	FEB	3	250	720	453.333					0				3	100	168	129.333	2	0.074	0.148	0.111
	MAR	5	50	450	326					0				4	40	90	71.5	4	0.074	0.148	0.111
	APR	4	140	400	297.5					1	0.84	0.84	0.84	1	30	30	30	3	0.074	0.185	0.123
	MAY	2	170	210	190					1	1.2	1.2	1.2	1	90	90	90	3	0.074	0.111	0.099
	JUN	8	50	600	265.625					2	3	10	6.5	5	50	190	102	7	0.074	0.259	0.148
	JUL	5	155	950	443					1	1	1	1	4	154	360	233.5	7	0.111	0.333	0.201
	AUG	4	200	950	452.5					0				3	70	84	77.333	4	0.037	0.222	0.139
	SEP	4	150	6500	1812.5					0				2	90	116	103	6	0.074	0.444	0.179
	OCT	7	300	920	482.857					2	0.8	2.48	1.64	3	60	810	344	8	0.038	0.37	0.167
	NOV	2	340	400	370					1	4	4	4	0				2	0.185	0.222	0.204
	DEC	2	450	650	550					0				2	50	150	100	2	0.074	0.074	0.074
17002105901	JAN	3	350	550	450					0				3	100	310	206.667	4	0.037	0.185	0.111
BM-7	FEB	2	380	1900	1140					0				2	130	216	173	1	0.037	0.037	0.037
	MAR	3	350	650	466.667					0				3	40	56	45.333	3	0.037	0.074	0.049
	APR	3	150	200	180					1	1	1	1	1	30	30	30	3	0.037	0.111	0.074
	MAY	2	180	210	195					1	1.1	1.1	1.1	1	80	80	80	4	0.029	0.185	0.072
	JUN	8	140	400	200.625					2	3	10	6.5	5	20	80	54	7	0.037	0.111	0.069
	JUL	4	150	1700	578.75					1	1	1	1	2	140	182	161	7	0.037	0.222	0.127
	AUG	3	100	1000	450					0				2	30	150	90	4	0.037	0.704	0.222
	SEP	4	50	1600	477.5					0				2	20	220	120	7	0.037	0.111	0.079
	OCT	6	81	600	261.833					2	0.9	1.22	1.06	2	40	50	45	8	0.021	0.259	0.091
	NOV	2	100	430	265					1	2	2	2	0				2	0.037	0.074	0.056
	DEC	2	450	650	550					0				2	30	170	100	2	0.037	0.074	0.056

Table 2: Location of Sampling Stations. Bancroft Area Mines. May - November 2000.

Madawaska Mine. Sampling Locations. May - Nov. 2000.								
Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
MM-LC	Siddon Lake. South end of lake approx. 50m from s. shore. Map Ref. 10 18 27122E 4989915N	✓	✓	✓	cores: 35 cm: 0-10; 10-20; 20-30 cm	3 reps.		Control lake; upriver of Bentley Lake. Black silty fine-grained sediments with some sand at bottom of core
MM-CS	Creek at north end of Bentley Lake, on upstream side of Bentley L. Rd. Map Ref. 10 18 27034E 499029N.	✓	✓	✓	cores: 20-25 cm: 0-10; 10-20 cm	3 reps		Stream control. Ponded area of stream adjacent to road. Black silty sand.
MM-1	Bentley Lake at north end of lake. Map Ref. 10 18 27049E 499010N	✓	✓	✓	cores: 40+cm: 0-10; 10-20; 20-30 cm	3 reps		Loose, watery surface layer of black fine-grained sediment, dark brown, flocculent deeper layers
MM-2	Bentley Lake at south end of lake beside mine site. Map Ref. 10 18 27038E 498972N	✓	✓	✓	cores: 40+cm: 0-10; 10-20; 20-30 cm	3 reps		Loose, watery surface layer of black fine-grained sediment, dark brown, flocculent deeper layers.
MM-3	Creek/outflow of Bentley Lake; east end of creek opposite tailings area. Map Ref. 10 18 27032E 4989355N	✓	✓	✓	cores: 20-25 cm: 0-10; 10-20 cm	3 reps		Top layer coarse detritus with plant roots and debris in clay, sand mix; bottom light brown soil-like sediment (dry & cohesive).
MM-4	Creek/outflow of Bentley Lake; at downstream end of lake just upstream of access road to mine site. Map Ref. 10 18 26959E 498861N	✓	✓	✓	cores: 30-35 cm; 0-10; 10-20; 20-30 cm	3 reps		Black organic sediment/ sand mix, very cohesive at bottom.

Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
MM-5	Bow Lake at east end of lake in deeper basin off mouth of Bentley Ck.. Map Ref. 10 18 269550E 498879N	✓	✓	✓	cores: 40 cm: 0-10; 10-20; 20-30 cm	3 reps		Black fine-grained, very loose & watery sediment. Very high conductivity at bottom.
MM-6	Bow Lake at northwest bend in lake. Map Ref. 10 18 268730E 498880N	✓	✓	✓	cores: 35-40 cm: 0-10; 10-20; 20-30 cm	3 reps		Loose, brown fine-grained sediment, similar to control lake, some fine-grained black material in top 10 cm.
MM-7	Bow Lake near south end of lake adjacent to bay on west side). Map Ref. 10 18 26843E 498764N	✓	✓	✓	cores: 35 cm: 0-10; 10-20; 20-30 cm	3 reps		Reddish brown flocculent layer (2-3 mm) over dark brown fine-grained silts.
MM-8	Small lake below Bow Lake (s. Side Hwy 28), near inlet. Map Ref. 10 18 268615E 4987165N	✓	✓	✓	cores: 40 cm: 0-10; 10-20; 20-30 cm	3 reps		Medium to dark brown organic sediment (fine-grained), flocculent.
MM-9	Small lake downstream of MM-8. Map Ref. 10 18 26829E 4986595N	✓	✓	✓	cores: 35-40 cm: 0-10; 10-20; 20-30 cm	3 reps		Very watery surface layer of flocculent organic muck (with peat); peaty layer approx 15 cm down (significant compaction of sediment in core)
MM-10	Below beaver pond, __km s. of Hwy 28 on Lower Faraday Rd. Map Ref. 10 18 26711E 498419N	✓	✓	✓	hand sampled to 10 cm	3 reps		Sand and gravel on bottom, up to 10 cm of fine loose organic silt at edges of pond.
MM-11	Below swampy area approx. 1 km upstream of Crowe River. Map Ref. 10 18 266125E 498254N	✓	✓	✓	none: hard substrate	none		Hard substrate (sand and gravel). Water samples only.
MM-12	Approx. 1 km downstream of confluence with Crowe R. Map Ref. 10 18 26643E 4981715N	✓	✓	✓	cores: 20 cm: 0-10; 10-20 cm	3 reps		Silt and detritus layer (~ 5 cm) overlying sandy silt.

Bicroft Mines. Sampling Locations. May - Nov. 2000								
Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
BM-LC	Centre Lake, north basin. Map Ref. 10 17 73245E 498846N	✓	✓	✓	cores: 35 cm: 0-10; 10-20; 20-30 cm	3 reps		fine-grained silty sediments, medium brown in colour, overlaid by 1-2 cm of loose, fine, organic detritus.
BM-1	Centre Lake, southwest basin near tailings dam. Map Ref. 10 17 73242E 498731N	✓	✓	✓	cores: 35-40 cm: 0-10; 10-20; 20-30 cm	3 reps		fine-grained silty sediments, medium brown in colour, overlaid by 1-2 cm of loose, fine, organic detritus
BM-2	South end of Auger Lake in tailings disposal area. Map Ref. 10 17 73299E 498648N	✓			cores: 20 cm: 0-10; 10-20 cm	3 reps		1-2 cm of organic sediment on top of fine-grained tailings.
BM-3	Deer Ck in beaver pond just below Centre Lake. Map Ref. 10 17 73339E 498712N	✓	✓		cores: 10 cm: 0-10 cm	3 reps		Stream control. Silty sediments with some coarse detritus and overlying rock and gravel.
BM-4	Trib. To Deer Ck., below outlet from beaver pond below Auger Lake. Map Ref. 10 17 733605E 498615N	✓	✓	✓	cores: 10 cm: 0-10 cm	3 reps		Leaf debris with silt and woody debris over sand (creek is ~1 m wide).
BM-6	Deer Ck, 0.5 km below mine at upper end of bay leading into Inlet Bay (Paudash L). Upstream of bridge. Map Ref. 10 17 73384E 4985845N	✓	✓	✓	Ekman (~10 cm)	3 reps		Brown fine-grained sediment with detritus (leaf debris) (up to 10 cm) overlying sand & gravel & rock.
BM-7	Paudash Lake at Inlet Bay. Map Ref. 10 17 73433E 498498N	✓	✓	✓	cores: 35-40 cm: 0-10; 10-20; 20-30 cm	3 reps		Brown silty, flocculent sediment with medium-brown deeper layer.

Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
BM-8	Paudash Lake between Stringer Is and Abrams Pt. Map Ref. 10 17 73234E 498309N	✓	✓	✓	cores: 40+cm: 0-10; 10-20; 20-30 cm	3 reps		Very loose, watery surface layers with plant detritus and roots, flocculent sediment. Brown deeper layers.
BM-9	Paudash Lake in Joe Bay. Map Ref. 10 17 73185E 4981500N	✓	✓	✓	cores 20-25 cm: 0-10; 10-20 cm	3 reps		Black silty sand, little organic matter.
BM-10	Lower Paudash Lake, ne. of Ransom Pt. Map Ref. 10 17 734955E 498248N	✓	✓	✓	cores: 35 cm: 0-10; 10-20; 20-30 cm	3 reps		Fine-grained brown silty sediment. Flocculent surface layers.
BM-11	Near middle of Lower Paudash L. GPS Ref. 10 18 263454E 4983814N	✓	✓		cores: 35-40 cm: 0-10; 10-20; 20-30 cm	3 reps.		Fine-grained watery surface layer grading to light brown flocculent fine-grained material (25-40 cm).

Canadian Dyno Mine. Sampling Locations. May- November 2000								
Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
DM-LC	Brough Lake, at south end of lake. Map Ref. 10 17 72876E 498243N	✓	✓	✓	cores: 30 cm: 0-10; 10-20; 20-30 cm	3 reps		fine-grained silty sediment, medium brown in colour; top 10 cm loose and watery, 10+cm firm and cohesive.
DM-SC	Farrel Creek, approx. 0.5 km north of mine entrance, beside Hwy 648. Map Ref. 10 17 72864E 4981295N	✓	✓	✓	cores: 5 cm: 0-5 cm	3 reps		organic detritus mixed with sand, overlying gravel.

Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
DM-1	Small lake downstream of Brough Lake, above tailings area. Map Ref. 10 17 72894E 498180N	✓	✓	✓	cores: 20 cm: 0-10; 10-20 cm	3 reps		Top layer (10 cm) loose silty sediments, deeper layer sand silt mix with peaty detritus.
DM-2	Farrel Lake, northeast end of Lake off discharge from tailings area. Map Ref. 10 17 72945E 498102N	✓	✓	✓	cores: 40 cm: 0-10; 102-0; 20-30 cm	3 reps		Surface-light brown silty sediment with organic matter (~2mm) over black fine-grained sediments with detritus (5 mm) over orange silt/clay/tailings mix (2 cm-20 cm) over very soft light grey clay.
DM-3	Farrel Lake, near outlet of Lake in deeper basin.. Map Ref. 10 17 72939E 498069N	✓	✓	✓	cores: 35-40 cm: 0-10; 10-20; 20-30 cm	3 reps		Top layer (0-10) black (anoxic) very watery. Deeper layers black, cohesive fine-grained sediment and detritus. No visible clay.
DM-4	Small lake (beaver pond) on Farrel Ck adjacent to Farrel Lake. Map Ref. 10 17 72904E 498068N	✓	✓	✓	cores: 30 cm: 0-10; 10-20; 20-30 cm	3 reps		Dark brown fine-grained silt/muck with detritus and plant roots (20cm) over peaty material (20+cm)
DM-5	Farrel Ck approx. 0.5 km downstream of Farrel Lake at Homestead Rd.. Map Ref. 10 17 72899E 498019N	✓	✓	✓	cores: 20 cm: 0-10; 10-20 cm	3 reps		Plant detritus (very dense) and silt in top 10 cm; brown soil-like sediment (very dry) in bottom 10 cm.
DM-6	Farrel Ck., below small Lake/pond approx.0.6 km upstream of mouth (along forest access rd). Map Ref. 10 17 72846E 4979485N	✓	✓	✓	cores: 30 cm: 0-10; 10-20; 20-30 cm	3 reps		Silt & detritus& sand in top 10 cm, sandy silt in 10-20 cm layer, peaty material in 20+ layer.
DM-7	At mouth of Farrel Ck (Eels L)		✓	✓	none	none		Not sampled for sediment - rock/ cobble/ gravel substrate.

Station	Location	Sample Type						Comments
		Water			Sediment	Benthos	Bioassay	
		May	Aug.	Nov				
DM-8	Eels Lake in north bay. Map Ref. 10 17 72836E 497849N	✓	✓	✓	Ekman (0-10 cm)	3 reps		Fine-grained silty material with abundant weeds.
DM-9	Eels Lake approx. 1.5 km south of DM-7. Map Ref. 10 17 72859E 497698N	✓	✓	✓	cores: 30-35 cm: 0-10; 10-20; 20-30 cm	3 reps		Dark brown surface layer of fine-grained silty sediments over deeper (15-20+cm) light brown peaty sediments.
DM-10	Eels Lake south of Devils Is/ Angels Is Map Ref. 10 17 72802E 497507N.	✓	✓	✓	cores: 25-30 cm: 0-10; 10-20; 20-30 cm	3 reps		Dark brown surface layer of fine-grained silty sediments over deeper (15-20+cm) light brown peaty sediments.
DM-11	Eels Lake south of Runway Is. Map Ref. 10 17 72690E 497433N	✓	✓		cores: 25-30 cm: 0-10; 10-20; 20-30 cm	as above		Dark brown surface layer of fine-grained silty sediments over deeper (15-20+cm) light brown peaty sediments.

Table 3: Distribution of Radionuclides, Metals and Nutrients in Surface Water, Madawaska, Dyno and Bicroft Mine Sites
May - November 2000. All values in mg/L unless otherwise indicated (Ra-226 in Bq/L).

	Ra-226 Diss. May	Ra-226 Susp. May	Ra-226 Total May	Ra-226 Diss. August	Ra-226 Susp. August	Ra-226 Total August	Ra-226 Diss. Nov.	Ra-226 Susp. Nov	Ra-226 Total Nov.	Uranium ug/L May	+/-	Uranium ug/L August	+/-	Uranium ug/L November	+/-	Arsenic ug/L May		Selenium ug/L May		Calcium May	+/-	Calcium August
MM-LC	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.42	0.06	0.45	0.05	0.5	0.05	0.5	<W	0.5	<W	21.8	1.31	17.3
MM-SC	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	1	0.08	1.5	0.09	1.51	0.11	0.5	<W	0.5	<W	27.7	1.66	37.6
MM-1Top	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	12.7	1	6.99	0.57	19.9	1.42	0.5	<W	0.5	<W	44.4	2.67	30.6
MM-1Bottom	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	41.1	3.56	35.1	2.31	20.4	1.18	0.5	<W	0.5	<W	110	6.6	109
MM-2 Top	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	13.9	1.3	7.35	0.46	20.1	1.09	0.5	<W	0.5	<W	44.3	2.66	30.6
MM-2Bottom	<0.01	0.07	0.08	<0.01	0.02	0.03	<0.01	<0.01	<0.02	48.8	3.77	68.4	4.06	46.2	2.8	0.5	<W	0.5	<W	105	6.28	159
MM-3	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	14.5	1.26	6.7	0.4	16.4	1.14	0.5	<W	0.5	<W	45.9	2.75	29.1
MM-4	0.02	<0.01	0.03	0.02	<0.01	0.03	0.01	<0.01	0.02	25.6	1.68	24	1.37	38.3	1.98	0.5	<W	0.5	<W	45.7	2.74	33.9
MM-5 Top	0.03	<0.01	0.04	0.02	<0.01	0.03	0.01	<0.01	0.02	23.8	2.24	43.6	2.54	55.7	3.48	0.5	<W	0.5	<W	50.2	3.01	42.9
MM-5 Bottom	0.22	0.05	0.27	0.37	0.01	0.38	0.05	<0.01	0.06	123	7.36	88.3	4.43	63.7	5.11	0.5	<W	0.5	<W	217	13.02	236
MM-6	0.03	<0.01	0.04	0.02	<0.01	0.03	0.02	<0.01	0.03	30.5	2.88	49.5	3.91	60	3.34	0.5	<W	0.5	<W	52.6	3.15	43.1
MM-6 Bottom	n.s.	n.s.	n.s.	0.15	<0.01	0.16	n.s.	n.s.	n.s.	n.s.		61.2	3.09	n.s		n.s.		n.s.		n.s.		57.8
MM-7	0.03	<0.01	0.04	0.03	<0.01	0.04	0.02	<0.01	0.03	51.1	4.38	47.4	2.51	56.2	3.31	0.5	<W	0.5	<W	53.3	3.2	44.9
MM-8	0.04	<0.01	0.05	0.02	0.03	0.05	0.01	<0.01	0.02	42.8	3.05	41.2	2.2	41.6	2.24	0.5	<W	0.5	<W	49.3	2.96	41.5
MM-9	0.02	<0.01	0.03	0.03	<0.01	0.04	0.03	<0.01	0.04	35	2.05	30.6	1.86	43.1	2.34	0.5	<W	0.5	<W	45.4	2.73	39.2
MM-10	0.02	<0.01	0.03	0.02	<0.01	0.03	<0.01	<0.01	<0.02	19.2	1.28	21.4	1.64	15.3	1.13	0.5	<W	0.5	<W	42.7	2.56	37.9
MM-11	0.02	<0.01	0.03	0.01	<0.01	0.02	<0.01	<0.01	<0.02	19.5	1.5	n.s.		14.4	0.87	0.5	<W	0.5	<W	41.4	2.48	
MM-12	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	2.97	0.25	2.35	0.2	7.08	0.75	0.5	<W	0.5	<W	16.3	0.98	14.9
DM-LC	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.15	0.03	0.28	0.05	0.09	0.05	0.5	<W	0.5	<W	3.33	0.2	3.09
DM-SC	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.27	0.02	0.64	0.06	0.19	0.05	0.5	<W	0.5	<W	10.6	0.63	14.4
DM-1	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.14	0.02	0.15	0.05	0.12	0.05	0.5	<W	0.5	<W	3.58	0.21	3.05
DM-2	0.17	<0.01	0.18	0.05	<0.01	0.06	0.08	<0.01	0.09	0.45	0.04	0.7	0.07	0.82	0.06	0.5	<W	0.5	<W	30.3	1.82	23.3
DM-3 Top	0.16	<0.01	0.17	0.05	<0.01	0.06	0.1	<0.01	0.11	0.45	0.04	0.68	0.07	0.8	0.06	0.5	<W	0.5	<W	30.6	1.84	21.9
DM-3 Bottom	0.57	0.01	0.58	0.37	<0.01	0.38	0.11	<0.01	0.12	1.44	0.15	1.82	0.16	0.8	0.07	0.5	<W	0.5	<W	32.9	1.97	32.1
DM-4	0.09	<0.01	0.1	0.07	<0.01	0.08	0.05	<0.01	0.06	0.79	0.08	0.67	0.09	0.82	0.1	0.5	<W	0.5	<W	26.1	1.57	22.2
DM-5	0.07	<0.01	0.08	0.2	<0.01	0.21	0.03	<0.01	0.04	0.68	0.07	1.05	0.1	1.09	0.06	0.5	<W	0.5	<W	23	1.38	21
DM-6	0.07	<0.01	0.08	0.07	<0.01	0.08	0.03	<0.01	0.04	0.62	0.07	0.77	0.08	0.95	0.08	0.5	<W	0.5	<W	22.9	1.38	20.3
DM-8	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.03	<0.01	0.04	0.21	0.02	0.23	0.05	1.21	0.1	0.5	<W	0.5	<W	9.26	0.56	8.47
DM-9	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.15	0.02	0.16	0.05	0.14	0.05	0.5	<W	0.5	<W	8.68	0.52	8.2
DM-10	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.1	0.01	0.13	0.05	0.09	0.05	0.5	<W	0.5	<W	8.66	0.52	8.43
DM-11	<0.01	<0.01	<0.02	n.s.	n.s.	n.s	n.s.	n.s.	n.s.	0.1	0.02	n.s.		n.s.		0.5	<W	0.5	<W	8.71	0.52	n.s.
BM-LC	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.04	0.02	0.1	0.05	0.08	0.05	0.5	<W	0.5	<W	3.61	0.22	3.23
BM-1 Top	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.05	0.01	0.15	0.05	0.08	0.05	0.5	<W	0.5	<W	3.85	0.23	3.26
BM-1 Bottom	n.s.	n.s.	n.s.	0.01	<0.01	0.02	n.s.	n.s.	n.s.	n.s.		0.2	0.05	n.s.		n.s.		n.s.		n.s.		4.74
BM-2	0.8	<0.01	0.81	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.37	0.04	n.s.		n.s.		0.5		0.5	<W	23.7	1.42	
BM-3	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	n.s.	n.s.	n.s.	0.05	0.02	0.09	0.05	n.s.		0.5	<W	0.5	<W	3.76	0.23	3.29
BM-4	0.44	0.11	0.55	0.37	<0.01	0.38	0.32	<0.01	0.33	5.75	0.58	9.56	0.64	12.6	0.74	0.5	<W	0.5	<W	98.9	5.94	106
BM-6	0.03	<0.01	0.04	0.01	<0.01	0.02	0.02	<0.01	0.03	1.1	0.08	8.17	0.46	1.96	0.13	0.5	<W	0.5	<W	6.49	0.39	5.18
BM-7 Top	0.02	<0.01	0.03	0.01	<0.01	0.02	0.02	<0.01	0.03	1.1	0.09	0.98	0.09	1.1	0.08	0.5	<W	0.5	<W	11.5	0.69	11.7
BM-7 Bottom	n.s.	n.s.	n.s.	0.04	<0.01	0.05	n.s.	n.s.	n.s.	n.s.		0.89	0.11			n.s.		n.s.		n.s.		11.6
BM-8	0.02	<0.01	0.03	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.38	0.05	0.35	0.05	0.25	0.05	0.5	<W	0.5	<W	9.8	0.59	8.88
BM-9	0.02	<0.01	0.03	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.15	0.02	0.18	0.05	0.15	0.05	0.5	<W	0.5	<W	10.2	0.61	9.24
BM-10	0.01	<0.01	0.02	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	0.35	0.03	0.28	0.05	0.22	0.05	0.5	<W	0.5	<W	11	0.66	10.6
BM-11	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	n.s.	n.s.	n.s.	0.35	0.03	0.28	0.05	n.s.		0.5		0.5	<W	11.1	0.66	10.4
PWQO	1									5						100 (5*)		100		na		

Table 3:

	Calcium November	+/-	Conduct. uS/cm May	Conduct. uS/cm August	Conduct. uS/cm November	pH May	pH August	pH November	Alkalinity mg/LCaCO3 May	N: ammonia +ammonium May	N: ammonia +ammonium August	N: ammonia +ammonium November	N: nitrite May	N: nitrite August	N: nitrite November	N: nitrate + nitrite May
MM-LC	21.8	1.31	245	221	264	7.82	8.18	7.53	48	0.088	0.016	0.1	0.006	0.005	0.004 <T	0.292
MM-SC	27.5	1.65	162	224	185	7.86	7.58	7.72	71	0.022	0.044	0.008 <T	0.001 <W	0.003 <T	0.004 <T	0.005 <W
MM-1Top	53.9	3.23	369	282	505	7.92	7.89	7.68	54	0.044	0.016	0.072	0.003 <T	0.001 <W	0.003 <T	0.094
MM-1Bottom	53.8	3.23	834	959	506	7.38	7.24	7.68	83.5	0.286	0.476	0.068	0.012	0.002 <T	0.004 <T	0.092
MM-2 Top	57.9	3.48	366	280	507	7.92	7.87	7.71	53.5	0.038	0.012	0.064	0.003 <T	0.002 <T	0.004 <T	0.1
MM-2Bottom	89.9	5.39	808	1200	823	7.39	7.13	7.19	76.5	0.12	0.494	0.316	0.009	0.002 <T	0.009	0.177
MM-3	51	3.06	389	279	483	7.8	7.53	7.63	53.5	0.036	0.024	0.028	0.003 <T	0.001 <W	0.004 <T	0.071
MM-4	50.7	3.04	392	332	490	7.7	7.46	7.61	57.5	0.024	0.04	0.036	0.003 <T	0.002 <T	0.004 <T	0.09
MM-5 Top	53.5	3.21	424	393	485	7.82	7.81	7.7	55	0.028	0.054	0.07	0.003 <T	0.002 <T	0.002 <T	0.085
MM-5 Bottom	134	8.05	1580	2050	1090	7.64	7.26	7.12	278	5.25	10.4	1.38	0.015	0.006	0.003 <T	0.135
MM-6	49.5	2.97	437	395	441	7.88	7.95	7.78	57	0.04	0.044	0.04	0.002 <T	0.002 <T	0.002 <T	0.084
MM-6 Bottom	n.s.		n.s.	499	n.s.	n.s.	7.29		n.s.	n.s.	0.166	n.s.	n.s.	0.018	n.s.	n.s.
MM-7	44.8	2.69	437	392	431	7.9	8.02	7.74	56	0.034	0.008 <T	0.04	0.003 <T	0.002 <T	0.004 <T	0.081
MM-8	40.5	2.43	394	379	400	7.85	7.86	7.73	57	0.024	0.012	0.054	0.004 <T	0.001 <W	0.003 <T	0.08
MM-9	41.4	2.48	365	358	398	7.88	7.62	7.66	56	0.05	0.028	0.052	0.003 <T	0.002 <T	0.008	0.054
MM-10	34	2.07	318	333	286	7.83	7.61	7.76	83.5	0.028	0.016	0.048	0.003 <T	0.004	0.003 <T	0.036
MM-11	31.6	1.9	316	n.s.	n.s.	8.04		n.a.	84	0.02	n.s.	n.s.	0.003 <T	n.s.	n.s.	0.019
MM-12	23.3	1.4	135	139	195	7.8	7.87	7.72	36.5	0.028	0.024	0.026	0.003 <T	0.002 <T	0.004 <T	0.029
DM-LC	3.01	0.18	30	29	30	7	7.04	6.82	7.5	0.036	0.016	0.008 <T	0.003 <T	0.001 <W	0.002 <T	0.026
DM-SC	9.53	0.57	90	118	95	7.21	6.87	7.22	27.5	0.032	0.012	0.008 <T	0.003 <T	0.003 <T	0.002 <T	0.008 <T
DM-1	3.08	0.18	31	30	32	6.89	6.86	6.76	7.5	0.024	0.008 <T	0.018	0.001 <W	0.001 <W	0.002 <T	0.029
DM-2	26.7	1.6	195	160	199	7.13	7.13	7.17	12.5	0.044	0.012	0.12	0.002 <T	0.001 <W	0.01	0.04
DM-3 Top	27.5	1.65	194	153	197	7.14	7.1	7.19	11.5	0.052	0.016	0.124	0.003 <T	0.001 <W	0.01	0.04
DM-3 Bottom	27.2	1.63	211	215	197	6.83	6.71	7.14	11	0.168	0.396	0.128	0.001 <W	0.004 <T	0.011	0.061
DM-4	22.6	1.36	172	151	170	7.18	6.84	7.2	17	0.052	0.01	0.062	0.001 <W	0.002 <T	0.06	0.03
DM-5	17.7	1.06	157	144	140	7.21	6.86	7.2	18.5	0.022	0.012	0.012	0.001 <W	0.001 <W	0.003 <T	0.008 <T
DM-6	15.5	0.93	151	141	128	7.23	7.16	7.25	26	0.016	0.004 <T	0.016	0.002 <T	0.002 <T	0.003 <T	0.005 <W
DM-8	16.4	0.98	59	58	130	7.33	7.29	7.42	17	0.038	0.028	0.012	0.004 <T	0.002 <T	0.003 <T	0.084
DM-9	7.77	0.47	57	59	61	7.39	7.43	7.25	16	0.032	0.02	0.016	0.002 <T	0.001 <W	0.003 <T	0.096
DM-10	8.26	0.5	56	58	59	7.45	7.47	7.32	17	0.048	0.008 <T	0.012	0.003 <T	0.001 <W	0.002 <T	0.11
DM-11	n.s.		56	n.s.	n.s.	7.45	n.s.	n.s.	18	0.04		n.s.	0.002 <T	n.s.	n.s.	0.107
BM-LC	3.32	0.2	41	42	45	6.83	6.87	6.73	6.5	0.038	0.016	0.036	0.002 <T	0.004 <T	0.004 <T	0.005 <W
BM-1 Top	3.87	0.23	49	47	51	6.9	6.96	6.7	6.5	0.048	0.008 <T	0.082	0.003 <T	0.004 <T	0.004 <T	0.011 <T
BM-1 Bottom	n.s.		n.s.	76	n.s.	n.s.	6.39	n.s.	n.s.	n.s.	1	n.s.	n.s.	0.024	n.s.	n.s.
BM-2	n.s.		157	n.s.	n.s.	6.79	n.s.	n.s.	7.5	0.052	n.s.	n.s.	0.002 <T	n.s.	n.s.	0.008 <T
BM-3	n.s.		46	45	n.s.	6.86	6.92	n.s.	6	0.052	0.004 <T	n.s.	0.003 <T	0.001 <W	n.s.	0.014 <T
BM-4	154	9.26	615	731	n.s.	7.3	7.22	7.16	19.5	0.024	0.032	0.076	0.003 <T	0.001 <W	0.003 <T	0.026
BM-6	16.6	1	68	58	1020	6.95	6.71	6.92	7	0.044	0.006 <T	0.024	0.003 <T	0.001 <W	0.002 <T	0.023 <T
BM-7 Top	12.2	0.73	98	106	162	7.54	7.62	7.4	24	0.052	0.008 <T	0.036	0.004 <T	0.001 <W	0.004 <T	0.064
BM-7 Bottom	n.s.		n.s.	105	114	n.s.	6.92	n.s.	n.s.	n.s.	0.002 <W	n.s.	n.s.	0.001 <W	n.s.	n.s.
BM-8	9.03	0.54	91	92	n.s.	7.56	7.59	7.51	22	0.036	0.002 <W	0.016	0.003 <T	0.001 <W	0.002 <T	0.058
BM-9	9.12	0.55	92	93	94	7.68	7.74	7.45	26	0.03	0.002 <W	0.01	0.003 <T	0.001 <W	0.002 <T	0.019 <T
BM-10	10.3	0.62	98	102	94	7.68	7.68	7.58	25.5	0.034	0.022	0.014	0.002 <T	0.001 <W	0.002 <T	0.046
BM-11	n.s.		98	102	102	7.67	7.73	n.s.	25	0.044	0.008 <T	n.s.	0.003 <T	0.001 <W	n.s.	0.05
PWQO			na			narrativea			20b				0.06c			narratived

Table 3:

	N: nitrate + nitrite August	N: nitrate + nitrite November	Phosphorus phosphate May		Phosphorus phosphate August		Phosphorus phosphate November		Al ug/L May	±	Al ug/L August	±	Al ug/L November	±	Ba ug/L May	±	Ba ug/L August	±	Ba ug/L November	±	Be ug/L May	±
MM-LC	0.155	0.155	0.0005	<W	0.0005	<W	0.002	<T	9.14	3	55		9.46	3	41.6	1.7	36		49.2	2	0.00526	0.03
MM-SC	0.005	0.03	0.001	<T	0.0005	<W	0.002	<T	20.7	3	25	<T	16.7	3	31.2	1.2	52		33	1.3	0.00555	0.03
MM-1Top	0.005	0.031	0.002	<T	0.0005	<W	0.001	<T	8.66	3	45	<T	10.2	3	27	1.1	28		28.8	1.2	0.00329	0.03
MM-1Bottom	0.005	0.033	0.003		0.002	<T	0.001	<T	27.9	3	255		6.44	3	37	1.5	31		28.8	1.2	0.0202	0.03
MM-2 Top	0.005	0.029	0.001	<T	0.0005	<W	0.001	<T	10.2	3	55		16.2	3	26.5	1.1	28		30.6	1.2	0.00864	0.03
MM-2Bottom	0.008	0.009	0.001	<T	0.0005	<W	0.001	<T	122	9	910		241	17	36.1	1.4	37		41.2	1.6	0.0455	0.03
MM-3	0.005	0.029	0.001	<T	0.0005	<W	0.001	<T	14.1	3	70		10.6	3	27	1.1	28		29.9	1.2	0.0047	0.03
MM-4	0.033	0.074	0.001	<T	0.0005	<W	0.002	<T	18.5	3	195		8.87	3	30.9	1.2	35		33.7	1.3	0.0106	0.03
MM-5 Top	0.015	0.036	0.001	<T	0.0005	<W	0.0005	<W	6.57	3	100		10.7	3	28.1	1.1	28		29.8	1.2	0.0101	0.03
MM-5 Bottom	0.005	0.022	0.001	<T	0.0005	<W	0.003		15.9	3	1230		16.4	3	44.9	1.8	65		33.1	1.3	0.0492	0.03
MM-6	0.008	0.038	0.001	<T	0.0005	<W	0.0005	<W	6.87	3	140		11.7	3	27.1	1.1	28		29.3	1.2	0.0087	0.03
MM-6 Bottom	0.032	n.s.	n.s.		0.0005	<W	n.s.		n.s.		145		n.s.		n.s.		35		n.s.		n.s.	
MM-7	0.008	0.036	0.001	<T	0.0005	<W	0.0005	<W	8.1	3	140		0.74	3	27.8	1.1	28		27.5	1.1	0.014	0.03
MM-8	0.017	0.088	0.001	<T	0.0005	<W	0.0005	<W	10.3	3	125		8.06	3	31.7	1.3	34		37.1	1.5	0.0117	0.03
MM-9	0.006	0.08	0.001	<T	0.0005	<W	0.0005	<W	10.7	3	90		74.2	5	32.9	1.3	35		38.8	1.6	0.0134	0.03
MM-10	0.029	0.073	0.001	<T	0.0005	<W	0.0005	<W	18.1	3	115		15.8	3	39.6	1.6	39		38.1	1.5	0.0168	0.03
MM-11	n.s.	n.s.	0.001	<T	n.s.		n.s.		18	3	n.s.		20.2	3	39.3	1.6	n.s.		35.7	1.4	0.00639	0.03
MM-12	0.012	0.073	0.001	<T	0.0005	<W	0.0005	<W	13.4	3	75		14.8	3	18.4	0.7	20		28	1.1	0.0078	0.03
DM-LC	0.005	0.014	0.001	<T	0.002	<T	0.0005	<W	7.58	3	5	<W	4.61	3	7.71	0.3	7	<T	7.26	0.3	0.00357	0.03
DM-SC	0.012	0.021	0.001	<T	0.002	<T	0.001	<T	30	3	315		24.1	3	17.9	0.7	34		15.6	0.6	0.0117	0.03
DM-1	0.012	0.031	0.001	<T	0.002	<T	0.003		11.4	3	65		8.08	3	8.56	0.3	9	<T	7.86	0.3	0.00921	0.03
DM-2	0.005	0.036	0.001	<T	0.002	<T	0.0005	<W	16.7	3	210		12	3	15.1	0.6	14		16.3	0.7	0.0123	0.03
DM-3 Top	0.005	0.037	0.001	<T	0.002	<T	0.001	<T	21.2	3	5	<W	14.4	3	15.4	0.6	12		16.7	0.7	0.0202	0.03
DM-3 Bottom	0.162	0.041	0.001	<T	0.002	<T	0.001	<T	53.1	4	45	<T	11.3	3	17.2	0.7	24		16.6	0.7	0.0258	0.03
DM-4	0.01	0.032	0.003		0.002	<T	0.0005	<W	15.6	3	65		12.5	3	14.8	0.6	16		15.4	0.6	0.0123	0.03
DM-5	0.005	0.03	0.004		0.002	<T	0.0005	<W	12.1	3	290		27.1	3	16.1	0.6	23		12.5	0.5	0.0112	0.03
DM-6	0.005	0.039	0.002		0.002	<T	0.0005	<W	17.4	3	175		35.1	3	17.6	0.7	21		12.1	0.5	0.0106	0.03
DM-8	0.012	0.065	0.004		0.001	<W	0.0005	<W	27.2	3	35		54.4	4	15.7	0.6	18		13.5	0.5	0.0078	0.03
DM-9	0.011	0.099	0.003		0.001	<T	0.001	<T	23.9	3	45		13.7	3	14.5	0.6	16		14.6	0.6	0.00752	0.03
DM-10	0.006	0.082	0.003		0.001	<T	0.0005	<W	21.2	3	5	<W	11.1	3	14.3	0.6	16		15.8	0.6	0.00526	0.03
DM-11	n.s.	n.s.	0.003		n.s.		n.s.		22.2	3	n.s.		n.s.		14.3	0.6	n.s.		n.s.		0.00555	0.03
BM-LC	0.005	0.022	0.003	<T	0.0005	<W	0.0005	<W	35.4	3	55		22.8	3	13.5	0.5	14		13.9	0.6	0.0148	0.03
BM-1 Top	0.005	0.019	0.004	<T	0.0005	<W	0.001	<T	30.1	3	105		28.3	3	13.8	0.6	14		15.6	0.6	0.0078	0.03
BM-1 Bottom	0.03	n.s.	n.s.		0.08		n.s.		n.s.		160		n.s.		n.s.		26		n.s.		n.s.	
BM-2	n.s.	n.s.	0.003		n.s.		n.s.		83.6	6	n.s.		n.s.		14.9	0.6	n.s.		n.s.		0.21	0.03
BM-3	0.014	n.s.	0.003		0.0005	<W	n.s.		30.2	3	30	<T	n.s.		13.6	0.5	13		n.s.		0.0112	0.03
BM-4	0.046	0.093	0.003		0.001	<T	0.001	<T	169	12	240		183	13	12	0.5	14		18.6	0.7	0.322	0.03
BM-6	0.022	0.041	0.003		0.001	<T	0.001	<T	44.3	3	345		28.8	3	13.1	0.5	19		13.7	0.5	0.0247	0.03
BM-7 Top	0.006	0.111	0.003		0.001	<T	0.001	<T	20.1	3	100		6.89	3	16.6	0.7	17		19.1	0.8	0.0129	0.03
BM-7 Bottom	0.272	n.s.	n.s.		0.001	<T	n.s.		n.s.		40	<T	n.s.		n.s.		18		n.s.		n.s.	
BM-8	0.005	0.038	0.003		0.004		0.001	<T	12.2	3	35	<T	6.11	3	13.1	0.5	14		13.5	0.5	0.00667	0.03
BM-9	0.005	0.031	0.003		0.001	<T	0.001	<T	4.28	3	25	<T	4.24	3	13.2	0.5	14		13.8	0.6	0.0016	0.03
BM-10	0.005	0.011	0.003	<T	0.001	<T	0.003		6.55	3	25	<T	4.38	3	13.2	0.5	14		14.2	0.6	0.00667	0.03
BM-11	0.005	n.s.	0.004		0.001	<T	n.s.		5.54	3	15	<T			13.4	0.5	14		n.s.		0.00667	0.03
PWQO			10/20/30e						75*						1000c						11/1100f	

Table 3:

	Be ug/L August	±	Be ug/L November	±	Cd ug/L May	±	Cd ug/L August	±	Cd ug/L November	±	Co ug/L May	±	Co ug/L August	±	Co ug/L November	±	Cr ug/L May	±	Cr ug/L August	±	Cr ug/L November	±	Cu ug/L May	±
MM-LC	1	<W	0.00554	0.03	0.0596	0.6	1	<W	0.32	0.9	0.00268	1.5	1	<W	0.0174	1.5	0.0341	1	1	<W	0.575	1	0.195	0.6
MM-SC	1	<W	0.0053	0.03	0.301	0.6	1	<W	0.292	0.9	0.0686	1.5	1	<W	0.307	1.5	0.323	1	1	<W	0.0562	1	0.255	0.6
MM-1Top	1	<W	0.00901	0.03	0.311	0.6	1	<W	0.163	0.9	0.335	1.5	1	<W	0.596	1.5	0.165	1	1	<W	1.28	1	0.0699	0.6
MM-1Bottom	1	<W	0.0116	0.03	0.0725	0.6	1	<W	0.509	0.9	0.484	1.5	1	<W	0.328	1.5	0.13	1	2	<T	0.0888	1	0.345	0.6
MM-2 Top	1	<W	0.0112	0.03	0.045	0.6	1	<W	0.208	0.9	0.173	1.5	1	<W	0.289	1.5	0.00659	1	1	<W	0.242	1	0.028	0.6
MM-2Bottom	1	<W	0.0754	0.03	0.24	0.6	1	<W	0.297	0.9	0.611	1.5	1	<W	0.514	1.5	0.57	1	1	<W	0.976	1	0.919	0.6
MM-3	1	<W	0.0101	0.03	0.0834	0.6	1	<W	0.193	0.9	0.382	1.5	1	<W	0.406	1.5	0.131	1	1	<W	0.259	1	0.16	0.6
MM-4	1	<W	0.0112	0.03	0.202	0.6	1	<W	0.039	0.9	0.366	1.5	1	<W	0.308	1.5	0.213	1	1	<W	0.464	1	0.512	0.6
MM-5 Top	1	<W	0.0183	0.03	0.268	0.6	1	<W	0.229	0.9	0.155	1.5	1	<W	0.386	1.5	0.193	1	1	<W	0.456	1	0.313	0.6
MM-5 Bottom	2	<T	0.0402	0.03	0.274	0.6	1	<W	0.291	0.9	0.75	1.5	1	<W	0.645	1.5	0.563	1	1	<W	0.166	1	0.464	0.6
MM-6	1	<W	0.0138	0.03	0.0343	0.6	1	<W	0.25	0.9	0.107	1.5	1	<W	1.24	1.5	0.173	1	1	<W	0.0717	1	0.0973	0.6
MM-6 Bottom	1	<W	n.s.		n.s.		1	<W	n.s.		n.s.		1	<W	n.s.		n.s.		1	<W	n.s.		n.s.	
MM-7	1	<W	0.0164	0.03	0.16	0.6	1	<W	0.108	0.9	0.335	1.5	1	<W	0.341	1.5	0.0272	1	1	<W	0.00348	1	0.0318	0.6
MM-8	1	<W	0.0138	0.03	0.212	0.6	1	<W	0.145	0.9	0.0673	1.5	1	<W	0.334	1.5	0.549	1	1	<W	0.0632	1	0.022	0.6
MM-9	1	<W	0.0168	0.03	0.098	0.6	1	<W	0.312	0.9	0.428	1.5	1	<W	0.109	1.5	0.000275	1	1	<W	0.133	1	0.345	0.6
MM-10	1	<W	0.00901	0.03	0.23	0.6	1	<W	0.0664	0.9	0.588	1.5	1	<W	0.242	1.5	0.213	1	1	<W	0.422	1	0.136	0.6
MM-11	n.s.		0.00975	0.03	0.101	0.6	n.s.		0.165	0.9	0.0224	1.5	n.s.		0.125	1.5	0.419	1	n.s.		0.0818	1	0.261	0.6
MM-12	1	<W	0.00938	0.03	0.312	0.6	1	<W	0.0178	0.9	0.145	1.5	1	<W	0.0734	1.5	0.391	1	2	<T	0.439	1	0.106	0.6
DM-LC	1	<W	0.00159	0.03	0.102	0.6	1	<W	0.166	0.9	0.345	1.5	1	<W	0.152	1.5	0.00659	1	4	<T	0.311	1	0.0736	0.6
DM-SC	1	<W	0.00863	0.03	0.114	0.6	1	<W	0.13	0.9	0.052	1.5	1	<W	0.319	1.5	0.13	1	3	<T	0.0205	1	0.446	0.6
DM-1	1	<W	0.0027	0.03	0.0557	0.6	1	<W	0.13	0.9	0.144	1.5	1	<W	0.152	1.5	0.268	1	3	<T	0.00348	1	0.04	0.6
DM-2	1	<W	0.00493	0.03	0.0296	0.6	1	<W	0.28	0.9	0.244	1.5	1	<W	0.255	1.5	0.0821	1	2	<T	0.201	1	0.285	0.6
DM-3 Top	1	<W	0.0101	0.03	0.736	0.6	1	<W	0.0368	0.9	0.517	1.5	1	<W	0.356	1.5	0.426	1	3	<T	0.125	1	0.0878	0.6
DM-3 Bottom	1	<W	0.0127	0.03	0.358	0.6	1	<W	0.279	0.9	0.155	1.5	1	<W	0.216	1.5	0.0209	1	4	<T	0.116	1	1.17	0.6
DM-4	1	<W	0.00715	0.03	0.0296	0.6	1	<W	0.333	0.9	0.264	1.5	1	<W	0.0191	1.5	0.281	1	3	<T	0.0888	1	0.207	0.6
DM-5	1	<W	0.0142	0.03	0.158	0.6	1	<W	0.0674	0.9	0.328	1.5	1	<W	0.175	1.5	0.0209	1	2	<T	0.405	1	0.0997	0.6
DM-6	1	<W	0.0142	0.03	0.386	0.6	1	<W	0.0593	0.9	0.439	1.5	1	<W	0.0201	1.5	0.014	1	3	<T	0.0461	1	0.0377	0.6
DM-8	1	<W	0.0186	0.03	0.141	0.6	1	<W	0.0888	0.9	0.586	1.5	1	<W	0.059	1.5	0.261	1	1	<W	0.191	1	0.381	0.6
DM-9	1	<W	0.000477	0.03	0.197	0.6	1	<W	0.229	0.9	0.0984	1.5	1	<W	0.424	1.5	0.13	1	3	<T	0.345	1	0.261	0.6
DM-10	1	<W	0.00567	0.03	0.0739	0.6	1	<W	0.0874	0.9	0.191	1.5	1	<W	0.355	1.5	0.185	1	2	<T	0.362	1	0.0639	0.6
DM-11	n.s.		n.s.		0.197	0.6	n.s.		n.s.		0.188	1.5	n.s.		n.s.		0.0272	1	n.s.		n.s.		0.189	0.6
BM-LC	1	<W	0.0053	0.03	0.0127	0.6	1	<W	0.173	0.9	0.0792	1.5	1	<W	0.266	1.5	0.357	1	1	<W	0.406	1	0.201	0.6
BM-1 Top	1	<W	0.00456	0.03	0.101	0.6	1	<W	0.0895	0.9	0.162	1.5	1	<W	0.086	1.5	0.0827	1	1	<W	0.771	1	0.034	0.6
BM-1 Bottom	1	<W	n.s.		n.s.		1	<W	n.s.		n.s.		1	<W	n.s.		n.s.		1	<W	n.s.		n.s.	
BM-2	n.s.		n.s.		0.0136	0.6	n.s.		n.s.		0.659	1.5	n.s.		n.s.		0.446	1	n.s.		n.s.		1.3	0.6
BM-3	1	<W	n.s.		0.0412	0.6	1	<W	n.s.		0.172	1.5	1	<W	n.s.		0.014	1	1	<W	n.s.		0.00785	0.6
BM-4	1	<W	0.407	0.03	0.314	0.6	1	<W	0.252	0.9	0.707	1.5	1	<W	0.252	1.5	0.0689	1	1	<W	1.58	1	0.452	0.6
BM-6	1	<W	0.0331	0.03	0.142	0.6	1	<W	0.194	0.9	0.18	1.5	1	<W	0.174	1.5	0.268	1	4	<T	0.106	1	0.0198	0.6
BM-7 Top	1	<W	0.00715	0.03	0.156	0.6	1	<W	0.00342	0.9	0.0411	1.5	1	<W	0.277	1.5	0.309	1	3	<T	0.294	1	0.291	0.6
BM-7 Bottom	1	<W	n.s.		n.s.		1	<W	n.s.		n.s.		1	<W	n.s.		n.s.		3	<T	n.s.		n.s.	
BM-8	1	<W	0.00307	0.03	0.251	0.6	1	<W	0.129	0.9	0.247	1.5	1	<W	0.165	1.5	0.117	1	3	<T	0.251	1	0.118	0.6
BM-9	1	<W	0.000106	0.03	0.117	0.6	1	<W	0.461	0.9	0.108	1.5	1	<W	0.718	1.5	0.0277	1	2	<T	0.464	1	0.261	0.6
BM-10	1	<W	0.00493	0.03	0.00266	0.6	1	<W	0.129	0.9	0.145	1.5	1	<W	0.581	1.5	0.247	1	4	<T	0.107	1	0.247	0.6
BM-11	1	<W	n.s.		0.0455	0.6	1	<W	n.s.		0.465	1.5	1	<W	n.s.		0.178	1	1	<W	n.s.		0.291	0.6
PWQO					0.1/0.5*g							0.6*					100						1/5*h	

Table 3:

	Cu ug/L August	±	Cu ug/L November	±	Fe ug/L May	±	Fe ug/L August	Fe ug/L November	±	Mg mg/L May	±	Mg mg/L August	Mg ug/L November	±	Mn ug/L May	±	Mn ug/L August	Mn ug/L November	±	Mo ug/L May	±	Mo ug/L August	±
MM-LC	9	<T	2.94	0.6	30.7	1.5	231	69.3	3.5	4.83	0.24	3.58	4.91	0.25	8.44	0.4	12	103	5.1	0.211	0.8	1	<W
MM-SC	6	<T	3.69	0.6	116	5.8	405	186	9.3	2.2	0.11	2.68	2.44	0.12	22.6	1.1	63	17.2	0.9	0.0391	0.8	1	<W
MM-1Top	6	<T	1.11	0.6	52.2	2.6	80	45.2	2.3	11.5	0.57	6.66	14.8	0.74	43.6	2.2	14	191	9.6	0.0391	0.8	1	<W
MM-1Bottom	6	<T	2.47	0.6	381	19.1	174	43.5	2.2	31.3	1.57	32.4	14.8	0.74	1430	71.3	2100	191	9.5	0.556	0.8	1	<W
MM-2 Top	6	<T	2.64	0.6	66.7	3.3	56	46.3	2.3	11.5	0.58	6.71	15.9	0.79	44.2	2.2	16	212	10.6	0.211	0.8	1	<W
MM-2Bottom	5	<T	1.31	0.6	466	23.3	833	4490	224.4	29.7	1.48	46.4	25.9	1.29	689	34.4	2130	1160	58	0.219	0.8	28	
MM-3	6	<T	2.27	0.6	65.9	3.3	98	80.5	4	12.1	0.61	6.45	14	0.7	37.8	1.9	28	104	5.2	0.133	0.8	1	<W
MM-4	17		2.79	0.6	92.9	4.6	162	95.4	4.8	11.7	0.59	7.3	13.4	0.67	48.4	2.4	70	48.7	2.4	0.392	0.8	1	<W
MM-5 Top	5	<T	2.31	0.6	6.57	1	77	56	2.8	12.4	0.62	9.6	13	0.65	68	0.1	14	64.5	3.2	0.909	0.8	2	<T
MM-5 Bottom	10		1.69	0.6	12.7	1	367	317	15.8	53.6	2.68	73.7	33.1	1.65	6730	336.5	11300	2010	100.6	1.25	0.8	7	<T
MM-6	9	<T	4.38	0.6	1.46	1	41	31.4	1.6	12.7	0.64	9.62	11.8	0.59	2.52	0.1	14	39.3	2	0.495	0.8	2	<T
MM-6 Bottom	10		n.s.		n.s.		150	n.s.		n.s.		12.4	n.s.		n.s.		738	n.s.		n.s.		1	<W
MM-7	12		1.4	0.6	18.6	1	153	54.9	2.7	12.8	0.64	10	10.7	0.53	40.6	2	12	75.8	3.8	0.0391	0.8	1	<W
MM-8	10		2.24	0.6	47.1	2.4	131	71.3	3.6	11.3	0.57	8.82	9.14	0.46	40.5	2	27	37	1.9	0.564	0.8	1	<W
MM-9	7	<T	1.89	0.6	94	4.7	212	393	19.7	10.2	0.51	8.15	9.39	0.47	33.6	1.7	56	67.5	3.4	0.392	0.8	2	<T
MM-10	9	<T	2.69	0.6	129	6.5	151	91.8	4.6	9.59	0.48	7.79	27.3	0.39	51.9	2.6	26	27.3	1.4	0.0471	0.8	1	<W
MM-11	n.s.		1.13	0.6	147	7.3	n.s.	102	5.1	9.12	0.46	n.s.	29.1	0.35	61.3	3.1	n.s.	29.1	1.5	0.219	0.8	n.s.	
MM-12	9	<T	1.99	0.6	69.4	3.5	208	135	6.8	3.31	0.17	2.79	4.83	0.24	21.9	1.1	18	16	0.8	0.384	0.8	1	<W
DM-LC	6	<T	1.87	0.6	96.1	4.8	93	53.1	2.7	0.641	0.03	0.562	0.596	0.03	35	1.8	9	20.8	1	1.07	0.8	1	<W
DM-SC	8	<T	1.77	0.6	307	15.4	2500	255	12.7	1.34	0.07	1.81	1.33	0.07	62.9	3.1	213	23	1.2	0.0391	0.8	1	<W
DM-1	13		1.89	0.6	139	7	135	82.5	4.1	0.681	0.03	0.535	0.61	0.03	41.4	2.1	39	32.2	1.6	0.298	0.8	3	<T
DM-2	1	<W	1.99	0.6	167	8.4	313	720	36	1.92	0.1	1.37	1.72	0.09	111	5.5	31	172	8.6	0.47	0.8	1	<W
DM-3 Top	4	<T	2.41	0.6	164	8.2	256	702	35.1	1.98	0.1	1.33	1.77	0.09	112	5.6	29	176	8.8	0.334	0.8	1	<W
DM-3 Bottom	7	<T	2.78	0.6	1420	70.9	2790	698	34.9	2.11	0.11	1.96	1.76	0.09	188	9.4	828	175	8.8	0.901	0.8	1	<W
DM-4	11		1.85	0.6	172	8.6	366	402	20.1	1.83	0.09	1.39	1.72	0.09	89.7	4.5	61	64.2	3.2	0.298	0.8	1	<W
DM-5	29		2.25	0.6	171	8.6	685	365	18.2	1.73	0.09	1.44	1.74	0.09	23	1.2	115	40	2	0.384	0.8	2	<T
DM-6	18		2.21	0.6	227	11.4	671	322	16.1	1.82	0.09	1.47	1.6	0.08	27.9	1.4	76	47	2.4	0.125	0.8	4	<T
DM-8	6	<T	2.4	0.6	102	5.1	574	441	22	1.01	0.05	0.845	1.67	0.08	25.4	1.3	53	123	6.2	0.0471	0.8	2	<W
DM-9	15		2.03	0.6	54.7	2.7	200	78.9	3.9	0.965	0.05	0.814	0.855	0.04	8.97	0.4	19	29	1.4	0.125	0.8	2	<T
DM-10	6	<T	2.11	0.6	34.9	1.7	377	61.4	3.1	0.953	0.05	0.836	0.9	0.04	6.76	0.3	10	54.5	2.7	0.642	0.8	1	<W
DM-11	n.s.		n.s.		35.2	1.8	n.s.	n.s.		0.96	0.05	n.s.	n.s.		6.42	0.3	n.s.	n.s.		0.728	0.8	n.s.	
BM-LC	9	<T	1.79	0.6	129	6.4	313	475	23.7	0.71	0.04	0.606	0.666	0.03	11	0.5	26	30.1	1.5	0.211	0.8	1	<W
BM-1 Top	10		3.07	0.6	142	7.1	233	662	33.1	0.753	0.04	0.603	0.733	0.04	20.9	1	26	75.9	3.8	0.642	0.8	1	<W
BM-1 Bottom	8	<T	n.s.		n.s.		7160	n.s.		n.s.		0.708	n.s.		n.s.		365	n.s.		n.s.		1	<W
BM-2	n.s.		n.s.		209	10.5	n.s.	n.s.		2.43	0.12	n.s.	n.s.		81.1	4.1	n.s.	n.s.		0.47	0.8	n.s.	
BM-3	6	<T	n.s.		120	6	265	n.s.		0.736	0.04	0.618	n.s.		16.3	0.8	23	n.s.		0.211	0.8	1	<W
BM-4	10		2.47	0.6	306	15.3	280	702	35.1	17.2	0.86	18	27.8	1.39	475	23.8	412	745	37.3	0.384	0.8	1	<W
BM-6	15		1.28	0.6	184	9.2	1400	261	13	1.2	0.06	0.929	3.15	0.16	52.1	2.6	335	57.2	2.9	0.556	0.8	1	<W
BM-7 Top	13		1.5	0.6	158	7.9	402	165	8.2	2.05	0.1	1.93	2.23	0.11	30.3	1.5	28	222	11.1	0.298	0.8	1	<W
BM-7 Bottom	10		n.s.		n.s.		195	n.s.		n.s.		1.91	n.s.		n.s.		54	n.s.		n.s.		2	<T
BM-8	9	<T	2.18	0.6	40.2	2	173	25.3	1.5	1.99	0.1	1.64	1.91	0.1	13	0.7	14	9.42	0.5	0.815	0.8	1	<W
BM-9	9	<T	2.47	0.6	18.3	1	95	24.9	1.5	2.34	0.12	1.98	2.09	0.1	8.44	0.4	13	28.1	1.4	0.211	0.8	1	<W
BM-10	9	<T	2.4	0.6	23.2	1.2	78	26.9	1.5	2.17	0.11	1.98	2.09	0.1	10.2	0.5	16	62.3	3.1	0.125	0.8	1	<W
BM-11	7	<T	n.s.		22.6	1.1	108	n.s.		2.17	0.11	1.94	n.s.		9.44	0.5	15	n.s.		0.384	0.8	1	<W
PWQO					300											<50i					10*			

Table 3:

	Mo ug/L November	±	Ni ug/L May	±	Ni ug/L August		Ni ug/L November	±	Pb ug/L May	±	Pb ug/L August		Pb ug/L November	±	Sr ug/L May	±	Sr ug/L August	Sr ug/L November	±	Ti ug/L May	±	Ti ug/L August	
MM-LC	0.287	0.8	0.902	1.5	2	<W	0.237	1.5	1.07	11	5	<W	2.49	11	145	5.8	116	169	6.7	0.171	0.3	1	<W
MM-SC	0.287	0.8	0.334	1.5	2	<W	0.328	1.5	2.77	11	5	<W	0.757	11	316	12.7	369	287	11.5	0.388	0.3	1	<W
MM-1Top	0.00881	0.8	0.666	1.5	2	<W	0.0318	1.5	5.54	11	5	<W	1.15	11	727	29.1	464	1110	44.6	0.352	0.3	1	<W
MM-1Bottom	0.0256	0.8	0.05	1.5	2	<W	0.417	1.5	2.42	11	5	<W	0.19	11	2040	81.5	2330	1110	44.5	0.323	0.3	1	<W
MM-2 Top	1.51	0.8	0.301	1.5	2	<W	1.32	1.5	0.496	11	5	<W	3.37	11	727	29.1	470	1190	47.7	0.51	0.3	1	<W
MM-2Bottom	0.6	0.8	1.64	1.5	2	<W	1.7	1.5	1.27	11	5	<W	0.177	11	1930	77.4	3340	1980	79.3	1.74	0.3	1	<W
MM-3	0.443	0.8	0.0163	1.5	2	<W	0.884	1.5	3.55	11	5	<W	2.8	11	751	30	447	1040	41.6	0.545	0.3	1	<W
MM-4	0.416	0.8	1.14	1.5	2	<W	0.701	1.5	0.286	11	5	<W	2.7	11	694	27.7	475	951	38	0.0354	0.3	1	<W
MM-5 Top	0.807	0.8	0.663	1.5	2	<W	0.959	1.5	1.07	11	5	<W	0.124	11	700	28	585	784	31.4	0.671	0.3	1	<W
MM-5 Bottom	0.416	0.8	0.451	1.5	2	<W	0.621	1.5	0.923	11	5	<W	0.866	11	1900	76	2070	1540	61.4	2.23	0.3	1	<W
MM-6	0.807	0.8	0.131	1.5	2	<W	0.6	1.5	3.11	11	5	<W	0.4	11	706	28.2	597	741	29.7	0.626	0.3	1	<W
MM-6 Bottom	n.s.		n.s.		2	<W	n.s.		n.s.		5	<W	n.s.		n.s.		789	n.s.		n.s.		1	<W
MM-7	0.573	0.8	0.839	1.5	2	<W	0.362	1.5	3.55	11	5	<W	2.64	11	704	28.1	621	679	27.2	0.656	0.3	1	<W
MM-8	0.573	0.8	0.446	1.5	2	<W	0.0882	1.5	3.13	11	5	<W	2.6	11	632	25.3	568	607	24.3	0.474	0.3	1	<W
MM-9	0.26	0.8	0.557	1.5	2	<W	0.811	1.5	0.499	11	5	<W	0.555	11	586	23.4	529	617	24.7	0.264	0.3	1	<W
MM-10	0.26	0.8	0.241	1.5	2	<W	0.647	1.5	4.62	11	5	<W	3.95	11	376	15	403	317	12.7	0.142	0.3	1	<W
MM-11	0.365	0.8	0.00592	1.5	n.s.		0.132	1.5	1.13	11	n.s.		0.126	11	356	14.2	n.s.	283	11.3	0.0388	0.3		
MM-12	0.104	0.8	0.158	1.5	2	<W	0.00964	1.5	0.425	11	5	<W	2.38	11	96.2	3.8	89	179	7.2	0.107	0.3	1	<W
DM-LC	0.209	0.8	0.0643	1.5	4	<T	0.308	1.5	0.78	11	5	<W	4.58	11	15.9	0.6	15	16.5	0.7	0.0239	0.3	1	<W
DM-SC	0.209	0.8	0.439	1.5	2	<W	0.103	1.5	1.56	11	5	<W	3.37	11	50.3	2	75	52.8	2.1	0.403	0.3	23	
DM-1	1.22	0.8	0.616	1.5	2	<W	0.25	1.5	1.21	11	5	<W	0.084	11	17	0.7	15	16.3	0.7	0.073	0.3	1	<W
DM-2	0.443	0.8	0.0682	1.5	2	<W	0.575	1.5	0.494	11	5	<W	2.78	11	85.1	3.4	69	88.3	3.5	0.274	0.3	1	<W
DM-3 Top	0.0256	0.8	0.225	1.5	2	<W	0.0338	1.5	3.38	11	5	<W	2.78	11	85.6	3.4	64	90.6	3.6	0.134	0.3	1	<W
DM-3 Bottom	0.0525	0.8	0.569	1.5	2	<W	0.451	1.5	1.47	11	5	<W	2.05	11	91	3.6	89	90	3.6	0.896	0.3	1	<W
DM-4	0.521	0.8	0.262	1.5	2	<W	1.88	1.5	4.83	11	5	<W	3.59	11	82.6	3.3	70	88.6	3.5	0.13	0.3	1	<W
DM-5	0.131	0.8	0.853	1.5	2	<W	0.833	1.5	1.42	11	5	<W	0.449	11	83.3	3.3	77	82.9	3.3	0.169	0.3	2	<T
DM-6	0.209	0.8	0.873	1.5	4	<T	0.783	1.5	0.564	11	10	<T	1.18	11	83	3.3	77	72.9	2.9	0.029	0.3	1	<W
DM-8	0.209	0.8	0.115	1.5	2	<W	0.77	1.5	0.57	11	5	<W	0.243	11	42.4	1.7	41	77.5	3.1	0.278	0.3	2	<T
DM-9	0.365	0.8	0.086	1.5	2	<W	1.17	1.5	3.48	11	5	<W	0.648	11	39.2	1.6	38	41.2	1.6	0.232	0.3	1	<W
DM-10	0.443	0.8	0.615	1.5	2	<W	0.255	1.5	4.76	11	5	<W	1.03	11	38.6	1.5	38	42.9	1.7	0.012	0.3	1	<W
DM-11	n.s.		0.578	1.5	n.s.		n.s.		2.42	11	n.s.		n.s.		38.4	1.5	n.s.	n.s.		0.217	0.3	n.s.	
BM-LC	0.209	0.8	0.669	1.5	2	<W	0.567	1.5	0.571	11	5	<W	6.03	11	29.1	1.2	29	34	1.4	0.324	0.3	1	<W
BM-1 Top	0.365	0.8	0.175	1.5	2	<W	1.03	1.5	0.495	11	5	<W	4.14	11	31.1	1.2	28	39.8	1.6	0.205	0.3	1	<W
BM-1 Bottom	n.s.		n.s.		2	<W	n.s.		n.s.		5	<W	n.s.		n.s.		39	n.s.		n.s.		2	<T
BM-2	n.s.		1.77	1.5	n.s.		n.s.		2.91	11	n.s.		n.s.		47.5	1.9	n.s.	n.s.		2.73	0.3	n.s.	
BM-3	n.s.		0.276	1.5	2	<W	n.s.		0.855	11	5	<W	n.s.		29.7	1.2	28	n.s.		0.188	0.3	1	<W
BM-4	0.287	0.8	3.06	1.5	2	<W	3.47	1.5	2.14	11	5	<W	2.99	11	273	10.9	296	479	19.2	0.444	0.3	1	<W
BM-6	0.443	0.8	1.35	1.5	4	<T	0.00595	1.5	1.5	11	5	<W	0.027	11	37	1.5	34	74.6	3	0.478	0.3	15	
BM-7 Top	0.287	0.8	0.16	1.5	2	<W	0.675	1.5	0.642	11	5	<W	1.49	11	53.9	2.2	55	65.3	2.6	0.0917	0.3	1	<W
BM-7 Bottom	n.s.		n.s.		2	<W	n.s.		n.s.		5	<W	n.s.		n.s.		53	n.s.		n.s.		1	<W
BM-8	0.6	0.8	0.0193	1.5	2	<W	0.468	1.5	0.64	11	5	<W	1.69	11	43.8	1.8	41	45.6	1.8	0.0574	0.3	1	<W
BM-9	0.834	0.8	0.411	1.5	2	<W	0.594	1.5	2.13	11	5	<W	1.55	11	40.3	1.6	37	42.4	1.7	0.0103	0.3	1	<W
BM-10	0.131	0.8	0.112	1.5	2	<W	0.256	1.5	1.56	11	5	<W	1.06	11	44.7	1.8	43	48.3	1.9	0.134	0.3	1	<W
BM-11	n.s.		0.199	1.5	2	<W	n.s.		1.21	11	5	<W	n.s.		45.2	1.8	43	n.s.		0.0205	0.3	1	<W
PWQO			25						1/3/5*j						10Bq/L					na			

Table 3:

	Ti ug/L November	±	Va ug/L May	±	Va ug/L August	±	Va ug/L November	±	Zn ug/L May	±	Zn ug/L August	±	Zn ug/L November	±
MM-LC	0.01453	0.3	0.103	0.9	1	<W	0.613	0.9	0.676	0.6	2	<T	1.91	0.6
MM-SC	0.118	0.3	0.109	0.9	1	<W	0.255	0.9	0.634	0.6	1	<W	2.74	0.6
MM-1Top	0.444	0.3	0.046	0.9	1	<W	0.183	0.9	1.3	0.6	7	<T	1.98	0.6
MM-1Bottom	0.656	0.3	0.608	0.9	1	<W	0.494	0.9	4.98	0.6	1	<W	2.74	0.6
MM-2 Top	0.618	0.3	0.398	0.9	1	<W	0.442	0.9	0.76	0.6	1	<W	1.57	0.6
MM-2Bottom	1.55	0.3	0.647	0.9	1	<W	2.3	0.9	11	0.8	1	<W	9.08	0.6
MM-3	0.459	0.3	0.13	0.9	1	<W	0.263	0.9	0.69	0.6	1	<W	2.42	0.6
MM-4	0.529	0.3	0.205	0.9	1	<W	0.528	0.9	0.943	0.6	3	<T	3.23	0.6
MM-5 Top	0.537	0.3	0.398	0.9	1	<W	0.127	0.9	0.0568	0.6	1	<W	1.7	0.6
MM-5 Bottom	1.59	0.3	0.518	0.9	1	<W	0.343	0.9	0.62	0.6	1	<W	2.74	0.6
MM-6	0.467	0.3	0.00414	0.9	1	<W	0.24	0.9	0.253	0.6	1	<W	3.06	0.6
MM-6 Bottom	n.s.		n.s.		1	<W	n.s.		n.s.		1	<W	n.s.	
MM-7	0.675	0.3	0.0794	0.9	1	<W	0.0327	0.9	0.648	0.6	9	<T	0.65	0.6
MM-8	0.552	0.3	0.506	0.9	1	<W	0.0839	0.9	1.06	0.6	1	<W	1.8	0.6
MM-9	1.93	0.3	0.235	0.9	1	<W	0.289	0.9	0.887	0.6	1	<W	4.16	0.6
MM-10	0.0623	0.3	0.0973	0.9	1	<W	0.272	0.9	0.915	0.6	1	<W	2.36	0.6
MM-11	0.00501	0.3	0.127	0.9	n.s.		0.203	0.9	1.7	0.6	n.s.		1.93	0.6
MM-12	0.0729	0.3	0.142	0.9	1	<W	0.374	0.9	0.929	0.6	1	<W	1.89	0.6
DM-LC	0.0114	0.3	0.0316	0.9	1	<W	0.161	0.9	1.63	0.6	3	<T	1.83	0.6
DM-SC	0.29	0.3	0.169	0.9	1	<W	0.0925	0.9	3.24	0.6	6	<T	2.44	0.6
DM-1	0.000767	0.3	0.175	0.9	7	<T	0.212	0.9	1.35	0.6	2	<T	2.23	0.6
DM-2	0.207	0.3	0.0281	0.9	1	<W	0.0275	0.9	1.97	0.6	1	<W	1.78	0.6
DM-3 Top	0.124	0.3	0.122	0.9	1	<W	0.238	0.9	2.64	0.6	2	<T	2.17	0.6
DM-3 Bottom	0.175	0.3	0.294	0.9	1	<W	0.0925	0.9	9.7	0.7	2	<T	4.21	0.6
DM-4	0.0877	0.3	0.112	0.9	1	<W	0.272	0.9	1.91	0.6	2	<T	1.91	0.6
DM-5	0.0735	0.3	0.229	0.9	1	<W	0.519	0.9	0.929	0.6	4	<T	2.59	0.6
DM-6	0.258	0.3	0.339	0.9	1	<W	0.144	0.9	1.86	0.6	3	<T	3.04	0.6
DM-8	0.716	0.3	0.0162	0.9	1	<W	0.306	0.9	1.34	0.6	2	<T	3.42	0.6
DM-9	0.0501	0.3	0.247	0.9	1	<W	0.189	0.9	1.77	0.6	1	<W	1.36	0.6
DM-10	0.0756	0.3	0.0615	0.9	1	<W	0.272	0.9	2.39	0.6	1	<W	2.06	0.6
DM-11	n.s.		0.0162	0.9	n.s.		n.s.		2.25	0.6	n.s.		n.s.	
BM-LC	0.271	0.3	0.154	0.9	1	<W	0.0583	0.9	2.58	0.6	2	<T	2.78	0.6
BM-1 Top	0.487	0.3	0.229	0.9	1	<W	0.417	0.9	2.67	0.6	2	<T	4.33	0.6
BM-1 Bottom	n.s.		n.s.		1	<W	n.s.		n.s.		4	<T	n.s.	
BM-2	n.s.		0.45	0.9	n.s.		n.s.		3.87	0.6	n.s.		n.s.	
BM-3	n.s.		0.058	0.9	1	<W	n.s.		3.12	0.6	3	<T	n.s.	
BM-4	0.247	0.3	0.046	0.9	1	<W	0.121	0.9	8.71	0.6	1	<W	8.27	0.6
BM-6	0.0523	0.3	0.291	0.9	2	<T	0.272	0.9	3.63	0.6	13		3.57	0.6
BM-7 Top	0.168	0.3	0.784	0.9	1	<W	0.0356	0.9	2.41	0.6	2	<T	1.95	0.6
BM-7 Bottom	n.s.		n.s.		1	<W	n.s.		n.s.		3	<T	n.s.	
BM-8	0.132	0.3	0.157	0.9	1	<W	0.0697	0.9	0.859	0.6	1	<W	1.61	0.6
BM-9	0.1	0.3	0.0401	0.9	1	<W	0.246	0.9	0.521	0.6	1	<W	1.72	0.6
BM-10	0.156	0.3	0.064	0.9	1	<W	0.212	0.9	1.04	0.6	1	<W	1.83	0.6
BM-11	n.s.		0.00773	0.9	1	<W	n.s.		0.887	0.6	1	<W	n.s.	
PWQO			7*						20*					

* Interim PWQO
na not available
a not to eceed 25% natural concentration
b unionized
c CCME guideline
d CCME avoid prolific weed growth
e TP 10-20ug/L in lakes, 30ug/L in rivers
f Caco3 <75mg/L - 11ug/L; >75mg/L - 1100ug/L
g Caco3 = 0-100mg/L - 0.1ug/L; >100mg/L - 0.5ug/L
h Caco3 = 0-20mg/L - 1ug/L; >20mg/L - 5ug/L
i CCME aesthetic objective
j Caco3 = <30mg/L - 1ug/L; 30-80mg/L - 3ug/L; >80mg/L - 5ug/L

Table 4: Distribution of Metals, Nutrients and Radionuclides in Sediment. May 2000
All values in ug/g dry weight unlessotherwise indicated.

		TKN mg/g	TOC mg/g	TP mg/g	Arsenic	Selenium	Barium	Cadmium	Chromium	Copper	Iron	Lead	Mercury
Madawaska Mine													
MM-LC	0-10	8	110	0.92	4.2	1.9	33	2	24	35	34000	93	0.11
	10-20	7.3	110	1	4.2	1.8	58	1.4	22	32	35000	50	0.09
	20-30	2.6	34	0.72	1.2	0.5	79	0.4 <T	13	14	21000	10	0.03 <T
MM-SC	0-10	2.9	46	1.1	1.5	0.4	99	0.3 <T	17	26	19000	16	0.03 <T
	10-20	0.4 '<T	67	1.1	1.9	0.7	130	0.4 <T	22	30	24000	21	0.06
MM-1	0-10	14	180	1.4	5.5	2.5	14	2.7	21	48	58000	110	0.15
	10-20	16	200	1.1	6.4	2.9	20	2.1	19	46	32000	72	0.14
	20-30	15	200	1	3.4	2	18	0.8 <T	16	43	26000	23	0.1
MM-2	0-10	14	170	1.7	7.5	2.4	19	4.1	20	58	55000	100	0.12
	10-20	16	200	1.3	7.3	2.5	21	2.3	18	47	33000	65	0.12
	20-30	13	200	0.96	2.1	2	30	0.8 <T	17	47	24000	12	0.09
MM-3	0-10	1.8	31	0.48	1.3	0.4 <T	43	0.2 <W	15	5	16000	16	0.04 <T
	10-20	1	20	0.4	1	0.3 <T	43	0.3 <T	17	5	19000	9 <T	0.06
MM-4	0-10	2.8	61	2.2	3.7	0.4 <T	100	0.3 <T	22	31	23000	24	0.04 <T
	10-20	2	38	2.1	3.5	0.4 <T	100	0.2 <W	21	32	24000	20	0.04 <T
	20-30	0.6	14	1.9	3.2	0.2 <W	94	0.2 <W	18	27	21000	13	0.03 <T
MM-5	0-10	4.2	63	1.9	6.3	1.3	47	0.2 <W	24	58	130000	86	0.08
	10-20	9	150	1.8	9.6	2.1	25	1.1	24	56	100000	160	0.12
	20-30	12	210	1	6	2.3	25	0.9 <T	18	45	61000	44	0.11
MM-6	0-10	7.1	110	1	6.2	1.7	58	1	22	39	47000	56	0.1
	10-20	7	110	0.88	2.1	1.4	60	0.3 <T	20	36	40000	13	0.16
	20-30	8.2	140	0.96	1.1	1.5	73	0.3 <T	22	43	41000	6 <T	0.07
MM-7	0-10	6.2	110	0.84	4.8	1.8	100	0.2 <W	20	40	170000	42	0.09
	10-20	7	120	0.56	1.4	1.5	51	0.2 <W	19	41	180000	11	0.05
	20-30	6.5	120	0.52	0.9 <T	1.4	41	0.2 <W	17	41	190000	9 <T	0.05
MM-8	0-10	13	160	1.2	2.5	1.9	25	1.8	17	39	40000	58	0.12
	10-20	9.8	130	0.84	2.6	1.6	42	1.4	15	32	30000	44	0.09
	20-30	11	140	0.68	2.2	1.5	65	0.9 <T	13	30	24000	24	0.09
MM-9	0-10	20	-	0.92	2.8	2.4	19	3.1	14	37	40000	69	0.15
	10-20	16	-	0.44	5.2	2.7	18	3.2	15	39	35000	61	0.14
	20-30	18	-	0.48	2.9	2	22	1.2	13	32	22000	16	0.09
MM-10	0-10	11	160	1	1.2	2.7	140	1.2	13	23	12000	39	0.11
MM-12	0-10	0.6	7	0.68	0.4 <T	0.2 <W	27	0.2 <W	6	5	7200	5 <T	0.02 <T
	10-20	0.3 <T	5	0.76	0.2 <W	0.2 <W	24	0.3 <T	6	5	6800	5 <T	0.02 <T
Dyno Mine													
DM-LC	0-10	5.3	95	0.98	7.2	1.9	83	1.4	11	20	24000	60	0.1
	10-20	3.9	91	0.86	2.2	1	71	0.6 <T	9	13	16000	14	0.05
	20-30	4	86	0.78	1.1	1	66	0.5 <T	8	11	16000	6 <T	0.05
DM-SC	0-10	0.1 <W	21	0.34	0.5 <T	0.2 <W	42	0.2 <W	10	6	11000	11	0.04 <T
DM-1	0-10	7.2	140	1.1	4.8	2.1	93	2.2	11	16	14000	70	0.12
	10-20	1.6	55	0.8	2.5	0.8 <T	64	0.8 <T	10	7	15000	32	0.05
DM-2	0-10	0.1 <W	7	0.28	4.5	0.4 <T	87	0.2 <W	33	61	65000	310	0.08
	10-20	0.1 <W	2 <T	0.3	4.9	0.2 <W	73	0.2 <W	44	60	66000	330	0.05
	20-30	0.1 <W	1 <W	0.28	5.3	0.2 <W	91	0.2 <W	36	55	46000	410	0.08
DM-3	0-10	5.2	110	0.96	7.4	1.6	34	0.2 <W	14	30	100000	180	0.12
	10-20	9.7	190	1.3	9	2	26	1	14	26	52000	99	0.13
	20-30	12	220	1.5	4.2	1.5	65	0.8 <T	10	24	32000	29	0.12
DM-4	0-10	17	220	1.2	5.1	2.3	21	2.5	11	50	57000	240	0.18
	10-20	14	220	0.92	4.7	2	38	2.9	10	46	37000	240	0.16
	20-30	14	250	0.66	2.1	1.3	33	1.6	7	22	10000	49	0.13

Table 4: Distribution of Metals, Nutrients and Radionuclides in Sediment. May 2000
All values in ug/g dry weight unlessotherwise indicated.

		TKN mg/g	TOC mg/g	TP mg/g	Arsenic	Selenium	Barium	Cadmium	Chromium	Copper	Iron	Lead	Mercury
DM-5	0-10	3.4	67	0.96	2.1	0.9 <T	62	0.5 <T	13	14	22000	23	0.07
	10-20	0.9	37	1.2	0.7 <T	0.7 <T	52	0.4 <T	15	8	11000	6 <T	0.07
DM-6	0-10	5.6	120	1.2	3.6	1.2	57	1.5	13	17	29000	46	0.12
	10-20	4.2	87	1.1	2.8	0.7 <T	51	1.1	12	13	23000	34	0.08
	20-30	1.6	43	0.68	1.6	0.3 <T	35	0.3 <T	8	6	10000	8 <T	0.08
DM-8	0-10	3.1	81	0.92	3	0.9 <T	120	1.2	18	14	18000	25	0.08
DM-9	0-10	5.2	100	1.6	10	1.6	91	1.8	24	22	36000	72	0.14
	10-20	4.7	92	1.5	7.1	1.1	140	1.3	23	18	27000	39	0.12
	20-30	4.4	95	1.5	5.5	1	130	1.1	24	16	26000	21	0.12
DM-10	0-10	8.7	140	1.7	23	2.5	110	2.9	31	34	61000	130	0.21
	10-20	8.1	140	1.6	20	2.2	52	2.6	28	31	48000	94	0.2
	20-30	8.6	150	1.8	14	1.6	120	1.9	26	26	47000	44	0.18
DM-11	0-10	5.6	100	1.6	17	1.8	200	2.3	27	25	51000	100	0.19
	10-20	3.8	86	1.8	6.2	1	110	1.2	23	15	40000	24	0.11
	20-30	3	61	1.7	2.3	0.6	78	0.4 <T	20	12	37000	6 <T	0.06
Bicroft Mine													
BM-LC	0-10	13	190	2.1	16	3	28	1.8	17	34	34000	130	0.25
	10-20	12	180	2	14	2.2	23	1.9	18	29	24000	97	0.23
	20-30	1.1	170	1.8	4.7	1.3	39	0.9 <T	14	27	17000	27	0.17
BM-1	0-10	12	190	2.3	18	3.4	27	1.7	18	46	48000	150	0.24
	10-20	12	180	2.4	17	2.7	41	2	19	40	34000	130	0.22
	20-30	12	190	2.6	6.2	1.6	130	1.1	16	31	22000	39	0.18
BM-2	0-10	0.2 <T	1 <W	1.6	16	0.3 <T	160	0.6 <T	33	95	41000	380	0.01 <W
	10-20	0.1 <W	1 <W	1	14	0.2 <W	170	0.7 <T	34	93	42000	440	0.01 <W
BM-3	0-10	2.2	43	0.84	3.6	0.5 <T	73	0.7 <T	13	7	14000	25	0.04 <T
BM-4	0-10	1.4	27	0.96	3.1	0.4 <T	59	0.6 <T	19	29	28000	35	0.04 <T
BM-6	0-10	2.7	41	0.74	2.9	0.6 <T	56	0.7 <T	16	22	20000	50	0.07
BM-7	0-10	9.1	140	2.2	12	2.2	100	2.7	27	39	54000	150	0.28
	10-20	8.4	140	1.8	10	1.7	120	2.1	24	28	34000	56	0.22
	20-30	8.7	160	1.7	3.9	1.3	130	1.5	23	26	28000	18	0.18
BM-8	0-10	16	230	0.44	5	2.5	54	0.8 <T	22	57	29000	35	0.12
	10-20	20	290	0.32	3.1	2.9	17	0.8 <T	22	78	37000	8 <T	0.09
	20-30	10	300	1	2.8	3.5	31	0.7 <T	20	79	42000	7 <T	0.08
BM-9	0-10	2.1	28	1.1	4.1	0.6 <T	78	0.6 <T	17	9	36000	23	0.04 <T
	10-20	2.1	25	1.7	2	0.4 <T	69	0.3 <T	18	9	34000	5 <T	0.02 <T
BM-10	0-10	26	130	0.28	12	2.5	21	3	24	39	32000	150	0.2
	10-20	21	130	0.24	9.1	1.6	74	1.6	21	29	22000	52	0.13
	20-30	6.2	140	1.1	3.5	1.1	70	1	18	26	17000	20	0.09
BM-11	0-10	6.6	110	1.2	12	2.1	58	2.7	25	37	38000	120	0.19
	10-20	8.6	100	1.2	10	1.5	74	1.7	24	29	28000	48	0.14
	20-30	8.4	110	1	3.1	1	110	0.9 <T	23	26	26000	18	0.1
PSQG:LEL		0.55	10	0.6	6		n.a.	0.6	26	16	20000	31	0.2
PSQG:SEL		4.8	100	2	33		n.a.	10	110	110	40000	250	2

* Saskatchewan sediment LEL and SEL (Kurias et al, 2000)

Table 4: Distribution c

All values

		Manganese	Nickel	Zinc	Beryllium		Magnesium	Aluminum	Calcium	Vanadium	Cobalt	Molybenum		Strontium	Titanium	Uranium
Madawaska Mine																
MM-LC	0-10	420	19	200	1	<T	3300	12000	7800	53	12	5.9		55	1000	13.6
	10-20	440	16	130	1.1	<T	3600	10000	7400	61	12	6.3		50	1100	14.3
	20-30	260	8.2	53	0.6	<T	2800	5800	4900	38	9.6	2.5		35	1100	7.6
MM-SC	0-10	300	13	78	0.5	<W	5600	9400	48000	42	8.6	0.7	<T	96	1400	6.5
	10-20	340	15	97	0.6	<T	6200	12000	30000	54	10	1.7	<T	98	1800	9.7
MM-1	0-10	2400	69	220	1.4	<T	4500	9900	16000	50	37	8.7		300	730	102
	10-20	1000	20	190	1	<T	4000	8400	15000	46	12	4.3		230	480	33.1
	20-30	900	13	120	0.9	<T	3600	7800	15000	48	9.1	5.2		190	400	28.1
MM-2	0-10	1800	110	250	1.8	<T	4800	10000	17000	53	50	8.6		380	770	239
	10-20	950	43	190	1.2	<T	4300	8500	16000	44	21	4.5		280	560	49.2
	20-30	610	15	110	1	<T	4200	8900	16000	51	11	7		230	500	30.5
MM-3	0-10	250	8.4	53	0.5	<W	2400	12000	4900	48	4	0.8	<T	65	1500	31.6
	10-20	240	80	44	0.5	<W	2900	13000	4400	52	4.4	1	<T	55	1700	12.4
MM-4	0-10	350	19	76	1.3	<T	8600	10000	14000	57	13	3.1		100	2300	153
	10-20	280	19	74	1.3	<T	8900	10000	13000	56	13	3		93	1600	121
	20-30	270	14	50	0.9	<T	8400	8600	12000	51	10	1.3	<T	73	2000	51.9
MM-5	0-10	1300	35	110	7		9200	15000	17000	67	22	17		140	1700	239
	10-20	780	27	160	12		8400	16000	18000	71	15	12		180	840	462
	20-30	590	13	120	2.1	<T	4800	8500	17000	79	12	8.6		160	560	147
MM-6	0-10	1200	34	150	3.5		4800	9800	10000	54	20	5.6		110	1000	226
	10-20	840	14	80	1.1	<T	4300	8400	9800	55	12	5.2		93	1100	91.1
	20-30	500	17	79	1.3	<T	4400	9200	10000	62	13	5.8		94	1000	101
MM-7	0-10	1200	11	120	3.5		2200	7500	9100	76	18	17		140	340	169
	10-20	610	0.5	<W	56	1.5 <T	1600	5800	7000	72	9.2	20		100	270	115
	20-30	430	0.5	<W	52	1.3 <T	1400	5000	6100	67	8.2	34		94	230	114
MM-8	0-10	800	37	220	2.1	<T	3800	8700	12000	36	23	3.8		140	790	148.8
	10-20	600	23	150	1.3	<T	3500	8300	9900	34	16	3.8		110	840	105.4
	20-30	440	13	97	0.6	<T	2800	6400	9300	31	12	4.6		100	610	50
MM-9	0-10	1500	46	260	1.7	<T	2900	6100	13000	22	21	6		150	430	201
	10-20	1400	48	240	1.7	<T	3000	6600	14000	29	22	9.2		150	480	255.7
	20-30	740	15	71	0.6	<T	2700	4500	14000	24	8.6	7.4		150	340	60.5
MM-10	0-10	130	15	110	0.8	<T	3500	6700	14000	29	7.2	1.9	<T	46	740	4.1
MM-12	0-10	130	3.6	20	<T	0.5 <W	1900	3100	3900	17	2.9	0.5	<W	22	840	3.3
	10-20	86	3.6	17	<T	0.5 <W	1800	2900	3800	18	2.3	0.5	<W	20	860	2.5
Dyno Mine																
DM-LC	0-10	670	14	160	1	<T	1600	7900	3800	25	6.1	4.2		18	420	23.2
	10-20	510	6.2	81	0.9	<T	1200	6500	2900	21	4.3	3.6		14	370	20.1
	20-30	490	6.5	84	0.9	<T	1100	6100	2800	20	5.4	6.1		14	330	21.3
DM-SC	0-10	420	4.1	36	0.5	<W	2400	5500	3800	26	4.4	1.2	<T	12	1200	2.8
DM-1	0-10	430	6.3	150	0.8	<T	2600	7900	5500	24	6.3	3.5		23	870	42.1
	10-20	360	5.2	92	0.7	<T	3100	7300	5300	26	5.2	2.1	<T	16	1300	16.6
DM-2	0-10	480	39	110	6.3		6600	15000	14000	56	12	58		32	1600	101.9
	10-20	440	64	130	9.3		5700	19000	42000	64	11	39		70	1300	141
	20-30	440	43	110	7		7700	16000	23000	53	9.9	42		51	1500	102
DM-3	0-10	580	22	120	1.9	<T	3500	7400	9600	39	10	18		42	670	87.6
	10-20	500	16	140	1.6	<T	2800	9100	10000	58	8.3	8.2		56	440	53
	20-30	570	8.4	100	1.2	<T	2500	9300	9400	58	7.6	6.7		55	310	23.8
DM-4	0-10	400	39	210	2.5		1600	9600	9400	22	21	5.7		33	420	212
	10-20	420	68	250	3.1		1200	9000	9000	20	26	4.1		35	340	290
	20-30	420	23	100	1.1	<T	870	5400	10000	20	8	4.3		38	240	61.5

Table 4: Distribution c
All values

		Manganese	Nickel	Zinc	Berylium	Magnesium	Aluminum	Calcium	Vanadium	Cobalt	Molybenum	Strontium	Titanium	Uranium
DM-5	0-10	620	11	76	1 <T	2400	8500	4500	34	16	4.2	33	800	38.7
	10-20	200	7.1	36	1 <T	2500	11000	4100	43	4	1.5 <T	36	820	32.1
DM-6	0-10	500	19	160	1.5 <T	2100	9800	5900	35	18	2 <T	64	800	67.2
	10-20	330	15	120	1.2 <T	2100	8500	5300	33	12	1.8 <T	89	840	47.7
	20-30	170	6.2	45	0.7 <T	1700	5500	3800	24	4.2	1.1 <T	63	780	19.5
DM-8	0-10	790	14	120	0.8 <T	3100	11000	6900	39	8.7	2 <T	37	1100	26.6
DM-9	0-10	1100	17	220	1.3 <T	4400	17000	8400	59	13	2.8	41	1100	15.7
	10-20	650	14	180	1.1 <T	4800	16000	8600	53	12	1.8 <T	42	1200	12.4
	20-30	640	13	150	1.1 <T	4600	15000	8400	49	12	1.9 <T	42	1100	11.2
DM-10	0-10	2100	20	340	1.6 <T	4600	22000	7400	73	17	5.1	41	1200	16.3
	10-20	1400	18	300	1.6 <T	4800	22000	7700	68	16	4.2	41	1000	15.9
	20-30	1300	14	240	1.7 <T	4400	22000	7600	62	16	5.2	43	910	16.5
DM-11	0-10	2900	17	310	1.7 <T	3500	19000	7000	64	17	5.6	37	1000	13.8
	10-20	1300	12	200	1.6 <T	3100	18000	7000	53	15	5	34	850	12.8
	20-30	1000	9.6	160	1.4 <T	3000	15000	6400	48	13	4.6	30	930	12
Bicroft Mine														
BM-LC	0-10	400	15	180	0.8 <T	1700	12000	4500	58	15	3.9	44	430	6
	10-20	400	14	170	0.8 <T	2200	13000	5200	56	14	2.8	47	480	5.9
	20-30	400	10	97	0.7 <T	2000	12000	5400	52	11	1.8 <T	50	390	5.7
BM-1	0-10	570	15	210	1 <T	1900	14000	5100	64	20	4.5	49	510	13.3
	10-20	530	15	180	0.9 <T	2400	14000	5700	65	17	3.5	53	600	9.8
	20-30	530	11	100	0.8 <T	2000	14000	6400	65	14	3	66	420	7.1
BM-2	0-10	1200	18	190	9.9	9100	19000	28000	73	9.8	13	71	2300	58.2
	10-20	1200	31	220	11	9200	21000	29000	71	14	10	84	1700	63
BM-3	0-10	350	8.6	81	0.7 <T	4600	7300	6000	38	8.7	1.6 <T	18	3000	16.4
BM-4	0-10	1100	34	190	4.1	5000	11000	8700	44	23	2.4 <T	33	1800	87.9
BM-6	0-10	380	13	130	1.5 <T	4300	7500	8200	36	9.3	1.3 <T	47	1400	346
BM-7	0-10	1300	29	460	3.8	3900	17000	9700	72	22	4.9	54	840	134
	10-20	1100	15	250	1.5 <T	4000	16000	11000	65	15	3.1	58	880	41.7
	20-30	860	12	170	1.1 <T	3700	15000	10000	60	14	2.9	57	790	24.8
BM-8	0-10	630	33	170	1.1 <T	3100	8900	8700	38	8.7	5.3	71	550	40.1
	10-20	510	38	140	1 <T	2800	6400	9400	35	8.4	8.7	110	410	39.9
	20-30	350	35	110	0.8 <T	3200	5800	9900	36	7.8	12	160	380	34.5
BM-9	0-10	910	7.9	130	0.6 <T	3700	8500	5500	46	10	2.4 <T	21	1200	7.1
	10-20	830	7.9	100	0.6 <T	4200	8900	6400	45	11	2.5	25	1300	7.4
BM-10	0-10	1100	22	300	1.2 <T	4300	14000	8600	52	12	3.5	39	760	30.5
	10-20	750	14	160	0.8 <T	4200	13000	9000	45	8.8	2.4 <T	41	790	14.4
	20-30	520	13	110	0.8 <T	3800	12000	8800	40	7.4	2.6	40	590	15
BM-11	0-10	1100	20	290	1.1 <T	4500	14000	7900	59	14	2.6	37	1000	26.4
	10-20	770	15	190	0.9 <T	4600	13000	8300	54	11	1.3 <T	38	1000	14.7
	20-30	570	13	130	0.8 <T	4300	12000	8200	50	11	1.1 <T	38	850	13.2
PSQG:LEL		460	16	120	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	*21
PSQG:SEL		1100	75	820	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	*390

* Saskatchewan sediment

Table 4:   Distribution c
          All values

		K-40 Bq/g	+/-	Th-228 Bq/g	Ra-226 Bq/g	Ra-228 Bq/g	U-238 Bq/g	Cs-137 Bq/g	U-235 Bq/g	Alph Bq/g	Beta Bq/g
Madawaska Mine											
MM-LC	0-10	0.9	0.17	0.04	0.03	0.07	0.2	0.06	0.1 <	1.2	0.7
	10-20	1.2	0.39	0.03	0.04	0.05 <	0.1 <	0.02	0.1 <	1.4	0.9
	20-30	0.7	0.92	0.02	0.02	0.05 <	0.1	0.01 <	0.1 <	0.61	1.1
MM-SC	0-10	0.4	0.61	0.04	0.03	0.05 <	0.1 <	0.01	0.1 <	0.73	0.98
	10-20	0.7	0.63	0.04	0.04	0.05 <	0.1	0.02	0.1 <	1.1	1.1
MM-1	0-10	10.6	0.13 <	0.06	0.16	0.07	0.93	0.06	0.1 <	6.6	3.5
	10-20	1.7	0.15	0.03	0.08	0.05 <	0.37	0.03	0.1 <	2.1	1.3
	20-30	1.4	0.1 <	0.02	0.02	0.05 <	0.2	0.01 <	0.1 <	1.4	0.8
MM-2	0-10	12	0.1	0.09	0.17	0.09	1.94	0.05	0.11	13	6.3
	10-20	2.5	0.17	0.04	0.07	0.07	0.34	0.04	0.1 <	3.6	1.8
	20-30	1.6	0.1 <	0.02	0.03	0.05 <	0.26	0.01 <	0.1 <	1.5	0.84
MM-3	0-10	1.6	0.58	0.03	0.05	0.05 <	0.37	0.02	0.1 <	2.1	1.6
	10-20	0.7	0.73	0.02 <	0.02	0.05 <	0.13	0.01 <	0.1 <	0.97	0.98
MM-4	0-10	7.7	0.53	0.1	0.24	0.12	1.43	0.01	0.1	14	4.7
	10-20	6	0.48	0.12	0.28	0.14	1.29	0.01	0.1 <	16	5.7
	20-30	2.7	0.48	0.08	0.22	0.13	0.56	0.01 <	0.1 <	6.6	2.4
MM-5	0-10	12	0.3 <	0.44	**12.17**	0.49	2.49	0.02 <	0.21	62	17
	10-20	23.2	0.28 <	0.55	**4.12**	0.63	4.3	0.03 <	0.28	83	25
	20-30	7.4	0.11 <	0.11	0.32	0.12	1.23	0.01 <	0.1 <	11	4.6
MM-6	0-10	11.4	0.36 <	0.1	**3.22**	0.15	2.44	0.01	0.2	41	14
	10-20	4.6	0.35	0.04	0.21	0.05	0.78	0.01 <	0.1 <	5.4	2.7
	20-30	5.1	0.44	0.06	0.05	0.05	0.91	0.01 <	0.1 <	3.7	2.3
MM-7	0-10	8.6	0.16 <	0.13	**1.1**	0.09	2.1	0.01	0.17	20	8.7
	10-20	5.8	0.15 <	0.05	0.21	0.05	0.97	0.01 <	0.1 <	4.9	2.5
	20-30	5.7	0.1 <	0.05	0.03	0.06	0.89	0.01 <	0.1 <	3.2	2.1
MM-8	0-10	7	0.25	0.06	**0.65**	0.06	1.3	0.03	0.18	19	7.7
	10-20	7.7	0.24 <	0.05 <	**0.73**	0.07 <	0.93	0.02	0.1 <	9.1	3.4
	20-30	2.9	0.23	0.04	0.41	0.05 <	0.42	0.01 <	0.1 <	2.8	1.4
MM-9	0-10	9.6	0.16 <	0.08	**1.1**	0.08	1.9	0.03	0.17	10	5.1
	10-20	9.9	0.14 <	0.04	**1.1**	0.05 <	2.3	0.03	0.18	12	7.4
	20-30	5.2	0.11 <	0.02	0.15	0.05 <	0.49	0.01 <	0.1 <	3.3	2.1
MM-10	0-10	0.3	0.41	0.04	0.07	0.05 <	0.12	0.02	0.1 <	3.7	1.9
MM-12	0-10	0.3	0.84	0.02	0.09	0.05 <	0.1 <	0.01	0.1 <	0.67	0.93
	10-20	0.2	0.75	0.02	0.07	0.05 <	0.1 <	0.01	0.1 <	0.41	0.88
Dyno Mine											
DM-LC	0-10	1.3	0.13 <	0.02 <	0.03	0.05 <	0.21	0.1	0.1 <	0.79	0.65
	10-20	1.3	0.15	0.02	0.02	0.05 <	0.14	0.02	0.1 <	0.41	0.45
	20-30	2.6	0.14	0.02	0.03	0.05 <	0.17	0.01 <	0.1 <	0.51	0.28
DM-SC	0-10	0.2	0.71	0.02 <	0.04	0.05 <	0.1 <	0.01	0.1 <	1.1	1
DM-1	0-10	2.9	0.42	0.02	0.06	0.05 <	0.4	0.15	0.1 <	3.4	2.3
	10-20	1	0.61	0.03	0.08	0.05 <	0.28	0.06	0.1 <	2.1	1.5
DM-2	0-10	0.2	1.3	6	**11**	7	6.4	0.05 <	0.77	300	63
	10-20	7.1	1.9	8.8	**9.2**	11	8.6	0.06 <	1	410	80
	20-30	5.1	1.7	6	**13**	7.4	6.7	0.05 <	0.77	310	73
DM-3	0-10	4.4	0.44 <	1.1	**9.2**	1.3	1.4	0.04 <	0.29	120	35
	10-20	2.7	0.32 <	0.46	**3.5**	0.52	0.62	0.01 <	0.1 <	50	15
	20-30	1.3	0.16 <	0.05	0.34	0.07	0.19	0.01	0.1 <	7.2	2.5
DM-4	0-10	10.6	0.18 <	0.27	**1.6**	0.28	2.3	0.03	0.37	41	14
	10-20	14.6	0.16 <	0.29	**1.3**	0.3	2.6	0.03	0.42	49	18
	20-30	3.1	0.17	0.07	0.42	0.06	0.68	0.01	0.1 <	15	5

Table 4: Distribution c
All values

		K-40 Bq/g	+/-	Th-228 Bq/g	Ra-226 Bq/g	Ra-228 Bq/g	U-238 Bq/g	Cs-137 Bq/g	U-235 Bq/g	Alph Bq/g	Beta Bq/g
DM-5	0-10	2.9	0.48	0.22	**1.8**	0.2	0.52	0.01	0.1 <	33	8
	10-20	1.8	0.42	0.04	*0.11*	0.05 <	0.27	0.01 <	0.1 <	4.3	1.8
DM-6	0-10	5.1	0.38	0.12	**1.5**	0.12	0.67	0.02	0.1	34	9.3
	10-20	2.6	0.33	0.09	**1**	0.1 <	0.46	0.02	0.1 <	25	7.9
	20-30	1.5	0.64	0.04 <	*0.36*	0.05 <	0.23	0.01	0.1 <	8.7	2.8
DM-8	0-10	2	0.53	0.03 <	*0.52*	0.05	0.21	0.04	0.1 <	8.3	3.1
DM-9	0-10	1.5	0.5	0.04	*0.3*	0.05 <	0.19	0.08	0.1 <	6.8	2.7
	10-20	1.1	0.31	0.03	*0.09*	0.05 <	0.11	0.02	0.1 <	1.9	1.1
	20-30	0.7	0.1 <	0.01 <	0.01	0.05 <	0.1 <	0.01 <	0.1 <	1.2	0.8
DM-10	0-10	0.9	0.16 <	0.02	*0.38*	0.05 <	0.17	0.13	0.1 <	3.8	1.8
	10-20	1.2	0.17	0.03	*0.13*	0.05 <	0.11	0.07	0.1 <	2.7	1.4
	20-30	1.2	0.19	0.03	*0.09*	0.05 <	0.15	0.01	0.1 <	1.7	0.76
DM-11	0-10	1.1	0.31	0.03	*0.12*	0.05 <	0.12	0.1	0.1 <	2.7	1
	10-20	1.2	0.27	0.02	0.05	0.05 <	0.15	0.02	0.1 <	1.6	0.85
	20-30	1.3	0.39	0.02	0.03	0.05 <	0.1	0.01	0.1 <	1.3	0.75
Bicroft Mine											
BM-LC	0-10	0.5	0.13	0.03	*0.06*	0.05 <	0.1 <	0.08	0.1 <	1.7	1.1
	10-20	0.2	0.15 <	0.02 <	0.03	0.05 <	0.1 <	0.05	0.1 <	0.91	0.75
	20-30	0.5	0.09	0.02	0.02	0.05 <	0.1 <	0.01	0.1 <	0.68	0.44
BM-1	0-10	1.5	0.17	0.04	*0.43*	0.05 <	0.1 <	0.08	0.1 <	4.6	1.6
	10-20	0.8	0.31	0.03	*0.21*	0.05 <	0.1 <	0.06	0.1 <	3	1.5
	20-30	0.5	0.13 <	0.02 <	0.04	0.05 <	0.1 <	0.01	0.1 <	1.1	0.63
BM-2	0-10	2.9	1.7	11	**9.9**	14	9.7	0.04 <	0.45	370	81
	10-20	3.2	2.1	14	**14**	16	12	0.06 <	0.49	390	94
BM-3	0-10	1.1	0.57	0.06	*0.09*	0.06	0.19	0.06	0.1 <	3.3	1.6
BM-4	0-10	4.5	0.94	1.1	**8.3**	1.5	1.6	0.04 <	0.1 <	86	21
BM-6	0-10	17.3	0.97	0.56	**0.79**	0.64	3.7	0.02	0.22	41	13
BM-7	0-10	6.8	0.48 <	0.84	**14**	0.89	1.6	0.05	0.24 <	120	44
	10-20	2.2	0.35 <	0.21	**4.3**	0.24	0.4	0.01	0.11 <	34	12
	20-30	1.3	0.17	0.05	*0.34*	0.05 <	0.23	0.01 <	0.1 <	4	1.7
BM-8	0-10	2.1	0.18 <	0.07	**0.71**	0.11	0.36	0.04	0.1 <	3.6	1.4
	10-20	2	0.24 <	0.07	*0.28*	0.09	0.34	0.02	0.1 <	1.2	0.74
	20-30	1.7	0.21 <	0.05	*0.1*	0.1	0.35	0.01 <	0.1 <	19	6.2
BM-9	0-10	0.8	0.5	0.02	*0.26*	0.04	0.1 <	0.03	0.1 <	5	2.1
	10-20	0.4	0.73	0.03 <	*0.06*	0.03	0.1	0.01	0.1 <	1.3	0.86
BM-10	0-10	1.5	0.17 <	0.08	**1.1**	0.07	0.26	0.01 <	0.1 <	6	2.5
	10-20	0.2	0.19	0.04 <	*0.18*	0.03	0.13	0.02	0.1 <	2.5	1.3
	20-30	0.8	0.19 <	0.03	0.04	0.05	0.14	0.01 <	0.1 <	0.74	0.44
BM-11	0-10	1.3	0.25	0.05	**1.1**	0.1	0.25	0.09	0.1 <	3.5	1.6
	10-20	1	0.3	0.03 <	*0.4*	0.04	0.12	0.03	0.1 <	0.92	0.92
	20-30	0.9	0.35	0.03	*0.06*	0.04	0.13	0.01 <	0.1 <	15	5.5
PSQG:LEL					*0.06*						
PSQG:SEL					***0.6**						

* Saskatchewan sediment

Table 5: Benthic Macroinvertebrates. Bancroft Area Mines. May, 2000

All values are number per m2

Station	Bicroft Mine BM-LC				BM-1			
Replicate	1	2	3*	Mean	1	2	3*	Mean
P. Coelenterata								
Hydra								
P. Nematoda								
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	0	11	0	4				
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	0	0	11	4				
O. Harpacticoida								
Cl. Ostracoda								
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera								
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae								
F. Chaoboridae	1335	710	1195	1080	431	807	764	667
F. Chironomidae	11	32	0	14	0	22	11	11
F. Dolichopodidae								
F. Empididae								
F. Simuliidae	0	11	0	4				
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda								
TOTAL NUMBER OF ORGANISMS	1346	764	1206	1105	431	829	775	678
Percent Chironomids	0.80	4.23	0.00		0.00	2.60	1.39	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	BM-2				BM-3			
Replicate	1	2	3*	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra					22	0	2583	868
P. Nematoda	0	11	11	7	22	1292	732	682
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma					0	86	0	29
P. Annelida								
Cl. Oligochaeta	0	11	0	4	151	861	947	653
Cl. Hirudinea					22	0	0	7
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	0	11	0	4	0	86	0	29
O. Harpacticoida								
Cl. Ostracoda					0	0	43	14
O. Amphipoda								
O. Isopoda					0	0	86	29
Cl. Insecta								
O. Coleoptera					0	172	0	57
O. Ephemeroptera	11	43	32	29	538	1292	603	811
O. Lepidoptera								
O. Megaloptera								
O. Odonata					32	86	0	39
O. Plecoptera								
O. Trichoptera					22	86	0	36
O. Diptera								
indeterminate								
F. Ceratopogonidae	22	0	22	14	43	431	258	244
F. Chaoboridae	0	11	11	7	0	0	43	14
F. Chironomidae	65	151	86	100	1722	5253	5985	4320
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda	32	108	32	57	65	86	43	65
Cl. Pelecypoda					0	86	0	29
TOTAL NUMBER OF ORGANISMS	129	344	194	222	2638	9817	11324	7926
Percent Chironomids	0.00	43.75	44.44		65.29	53.51	52.85	

* lowest practical level

Table 5: Benthic Macroinverte

All values are number per m2

Station	BM-4				BM-6			
Replicate	1	2	3*	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					215	129	0	115
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma	43	0	0	14				
P. Annelida								
Cl. Oligochaeta	215	258	129	201	226	237	431	298
Cl. Hirudinea					43	0	0	14
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina								
O. Harpacticoida					301	0	0	100
Cl. Ostracoda								
O. Amphipoda					0	86	258	115
O. Isopoda								
Cl. Insecta								
O. Coleoptera					0	97	344	147
O. Ephemeroptera					0	0	172	57
O. Lepidoptera								
O. Megaloptera	129	0	0	43				
O. Odonata								
O. Plecoptera	11	0	0	4				
O. Trichoptera					86	0	86	57
O. Diptera								
indeterminate								
F. Ceratopogonidae	129	43	86	86	172	172	689	344
F. Chaoboridae								
F. Chironomidae	301	43	431	258	560	861	517	646
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae	0	86	0	29				
P. Mollusca								
Cl. Gastropoda					0	0	258	86
Cl. Pelecypoda	1012	258	1033	768	172	388	700	420
TOTAL NUMBER OF ORGANISMS	1841	689	1679	1403	1776	1970	3455	2400
Percent Chironomids	16.37	6.25	25.64		31.52	43.72	14.95	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	BM-7				BM-8			
Replicate	1	2	3*	Mean	1	2	3*	Mean
P. Coelenterata								
Hydra								
P. Nematoda	0	0	11	4				
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	0	0	22	7				
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	32	0	22	18	22	0	11	11
O. Harpacticoida								
Cl. Ostracoda	0	0	22	7	22	0	22	14
O. Amphipoda					205	22	97	108
O. Isopoda					108	11	86	68
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera					22	43	0	22
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera					22	0	11	11
O. Diptera								
indeterminate								
F. Ceratopogonidae	0	0	11	4				
F. Chaoboridae	667	452	463	527	0	0	22	7
F. Chironomidae	183	118	151	151	517	205	409	377
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda					75	22	0	32
TOTAL NUMBER OF ORGANISMS	883	570	700	718	991	302	657	650
Percent Chironomids	20.73	20.75	21.54		52.13	67.70	62.29	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	BM-9				BM-10			
Replicate	1	2*	3	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda	22	22	11	18	22	0	0	7
P. Platyhelminthes								
Cl. Turbellaria	0	0	11	4				
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	377	129	32	179	22	86	11	39
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina					11	11	43	22
O. Harpacticoida								
Cl. Ostracoda	11	0	0	4	0	75	32	36
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera								
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae	11	0	0	4				
F. Chaoboridae	43	22	22	29	614	592	936	714
F. Chironomidae	86	86	183	118	258	614	377	416
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda	0	54	11	22	0	11	0	4
TOTAL NUMBER OF ORGANISMS	549	312	269	377	926	1389	1399	1238
Percent Chironomids	15.69	27.59	67.94		27.91	44.19	26.92	

* lowest practical level

Table 5: Benthic Macroinverte

All values are number per m2

Station	BM-11				Dyno Mine DM-SC			
Replicate	1	2*	3	Mean	1*	2	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					43	43	65	50
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	549	194	280	341	603	947	388	646
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	65	22	22	36				
O. Harpacticoida					129	0	0	43
Cl. Ostracoda	0	11	0	4				
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera								
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera					22	65	0	29
O. Diptera								
indeterminate								
F. Ceratopogonidae	11	0	0	4	0	43	0	14
F. Chaoboridae	1033	958	484	825	43	0	0	14
F. Chironomidae	237	151	118	169	990	1249	517	919
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda					43	22	0	22
Cl. Pelecypoda					0	32	32	22
TOTAL NUMBER OF ORGANISMS	1894	1335	904	1378	1873	2400	1001	1758
Percent Chironomids	12.50	11.29	13.10		52.87	52.02	51.61	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	DM-LC				DM-1			
Replicate	1	2	3*	Mean	1*	2	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					86	172	86	115
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta					0	86	0	29
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina					43	86	0	43
O. Harpacticoida								
Cl. Ostracoda								
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera					43	86	0	43
O. Lepidoptera								
O. Megaloptera								
O. Odonata					11	32	11	18
O. Plecoptera								
O. Trichoptera					0	86	0	29
O. Diptera								
indeterminate								
F. Ceratopogonidae	0	22	0	7				
F. Chaoboridae	0	32	0	11				
F. Chironomidae	129	194	97	140	1593	2756	1206	1851
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda					11	86	0	32
Cl. Pelecypoda	140	248	226	205	11	97	0	36
TOTAL NUMBER OF ORGANISMS	269	495	323	362	1798	3488	1302	2196
Percent Chironomids	48.00	39.13	30.00		88.62	79.01	92.56	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	DM-2				DM-3			
Replicate	1*	2	3	Mean	1*	2	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda	11	11	0	7				
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	43	54	11	36				
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina								
O. Harpacticoida								
Cl. Ostracoda								
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera	11	32	22	22	0	0	22	7
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera	0	11	0	4				
O. Diptera								
indeterminate								
F. Ceratopogonidae	215	108	226	183				
F. Chaoboridae					1324	1442	936	1234
F. Chironomidae	344	764	280	463	86	75	65	75
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda	11	11	0	7				
TOTAL NUMBER OF ORGANISMS	635	990	538	721	1410	1518	1023	1317
Percent Chironomids	54.24	77.17	52.00		6.11	4.96	6.32	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

	DM-4				DM-5			
Station / Replicate	1	2	3*	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					43	129	86	86
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	172	0	43	72	2196	2454	2153	2268
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina								
O. Harpacticoida								
Cl. Ostracoda					0	0	258	86
O. Amphipoda					0	43	0	14
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera					0	43	86	43
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera					0	0	86	29
O. Diptera								
indeterminate								
F. Ceratopogonidae					0	43	172	72
F. Chaoboridae								
F. Chironomidae	388	258	560	402	947	1550	1636	1378
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae					0	32	11	14
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda	0	129	43	57	0	0	86	29
Cl. Pelecypoda					0	86	11	32
TOTAL NUMBER OF ORGANISMS	560	388	646	531	3186	4381	4586	4051
Percent Chironomids	69.23	66.67	86.67		29.73	35.38	35.68	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

| Station | DM-6 | | | | DM-8 | | | |
Replicate	1*	2	3	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda	258	86	0	115	65	129	215	136
P. Platyhelminthes								
Cl. Turbellaria					43	86	215	115
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	86	431	2153	890	0	0	172	57
Cl. Hirudinea					22	0	0	7
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina					22	0	86	36
O. Harpacticoida	0	0	775	258	0	43	0	14
Cl. Ostracoda								
O. Amphipoda	86	0	0	29	248	258	689	398
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera	0	0	86	29	0	32	11	14
O. Lepidoptera								
O. Megaloptera								
O. Odonata	22	22	11	18	0	11	43	18
O. Plecoptera								
O. Trichoptera	0	0	86	29	344	258	764	456
O. Diptera								
indeterminate	172	86	0	86				
F. Ceratopogonidae	172	0	172	115	65	129	344	179
F. Chaoboridae					22	0	0	7
F. Chironomidae	1119	1033	2239	1464	2239	3229	6545	4004
F. Dolichopodidae								
F. Empididae					0	0	43	14
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda	43	118	43	68	258	172	388	273
Cl. Pelecypoda					0	786	1292	692
TOTAL NUMBER OF ORGANISMS	1959	1776	5565	3100	3327	5134	10807	6423
Percent Chironomids	57.15	58.18	40.23		67.30	62.90	60.56	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	DM-9				DM-10			
Replicate	1	2	3*	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					43	0	0	14
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	0	11	22	11				
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina					43	0	0	14
O. Harpacticoida								
Cl. Ostracoda								
O. Amphipoda					86	43	22	50
O. Isopoda					0	0	11	4
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera								
O. Lepidoptera								
O. Megaloptera					0	11	0	4
O. Odonata								
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae	11	22	11	14	0	0	22	7
F. Chaoboridae	11	22	11	14	0	0	11	4
F. Chironomidae	205	205	183	197	560	301	129	330
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda								
TOTAL NUMBER OF ORGANISMS	226	258	226	237	732	355	194	427
Percent Chironomids	90.48	79.17	80.95		76.48	84.81	66.42	

* lowest practical level

Table 5: Benthic Macroinverte

All values are number per m2

Station	DM-11				Madawaska Mine MM-SC			
Replicate	1	2*	3	Mean	1	2	3*	Mean
P. Coelenterata								
Hydra								
P. Nematoda					0	0	86	29
P. Platyhelminthes								
Cl. Turbellaria	0	11	11	7				
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	0	65	11	25	129	431	549	370
Cl. Hirudinea					0	0	22	7
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina					0	0	22	7
O. Harpacticoida								
Cl. Ostracoda	0	32	22	18	0	86	0	29
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera					43	0	0	14
O. Ephemeroptera	0	0	11	4	43	86	22	50
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae	22	0	0	7	43	258	151	151
F. Chaoboridae	11	11	11	11				
F. Chironomidae	280	323	398	334	258	1119	409	596
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda					43	0	0	14
Cl. Pelecypoda					301	301	86	230
TOTAL NUMBER OF ORGANISMS	312	442	463	406	861	2282	1346	1496
Percent Chironomids	89.66	73.13	86.00		30.00	49.06	30.39	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	MM-LC				MM-1			
Replicate	1	2	3*	Mean	1*	2	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda	86	344	75	169				
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	1905	3595	3175	2892				
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	11	32	11	18	11	0	0	4
O. Harpacticoida								
Cl. Ostracoda	22	32	43	32				
O. Amphipoda								
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera								
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae	0	11	0	4				
F. Chaoboridae	0	0	11	4	75	129	0	68
F. Chironomidae	527	2691	893	1371	172	151	97	140
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda								
TOTAL NUMBER OF ORGANISMS	2551	6706	4209	4489	258	280	97	212
Percent Chironomids	20.68	40.13	21.23		66.67	53.85	100.00	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	MM-2				MM-3			
Replicate	1	2*	3	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					1389	0	86	492
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma					86	43	0	43
P. Annelida								
Cl. Oligochaeta	11	0	0	4				
Cl. Hirudinea	0	11	0	4				
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	0	0	11	4				
O. Harpacticoida								
Cl. Ostracoda	0	0	22	7				
O. Amphipoda					0	86	0	29
O. Isopoda								
Cl. Insecta								
O. Coleoptera					904	560	344	603
O. Ephemeroptera					0	43	0	14
O. Lepidoptera					0	43	0	14
O. Megaloptera								
O. Odonata					118	129	0	83
O. Plecoptera								
O. Trichoptera	0	0	11	4	86	0	43	43
O. Diptera								
indeterminate								
F. Ceratopogonidae	0	0	11	4	6469	1464	2325	3419
F. Chaoboridae	75	97	280	151				
F. Chironomidae	377	678	1539	865	603	86	129	273
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda					97	54	0	50
Cl. Pelecypoda					32	420	86	179
TOTAL NUMBER OF ORGANISMS	463	786	1873	1041	9784	2928	3014	5242
Percent Chironomids	81.40	86.28	82.18		6.16	2.94	4.29	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	MM-4				MM-5			
Replicate	1*	2	3	Mean	1	2	3*	Mean
P. Coelenterata								
Hydra								
P. Nematoda	0	86	0	29	0	54	0	18
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	0	86	43	43	0	11	0	4
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	0	0	43	14				
O. Harpacticoida	0	258	0	86				
Cl. Ostracoda					32	452	75	187
O. Amphipoda	172	0	86	86				
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera	538	431	689	553				
O. Lepidoptera								
O. Megaloptera	108	108	0	72				
O. Odonata	0	0	86	29				
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae	172	0	172	115	11	0	0	4
F. Chaoboridae					11	22	11	14
F. Chironomidae	1894	3014	1722	2210	75	183	441	233
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda	86	0	129	72				
TOTAL NUMBER OF ORGANISMS	2971	3983	2971	3308	129	721	527	459
Percent Chironomids	63.77	75.67	57.97		58.33	25.37	83.67	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	MM-6				MM-7			
Replicate	1	2*	3	Mean	1*	2	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda								
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta	43	237	43	108	22	11	11	14
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	0	43	11	18	11	0	0	4
O. Harpacticoida								
Cl. Ostracoda	11	32	108	50	75	0	65	47
O. Amphipoda	43	22	86	50	11	32	11	18
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera	0	0	22	7				
O. Lepidoptera								
O. Megaloptera								
O. Odonata								
O. Plecoptera								
O. Trichoptera								
O. Diptera								
indeterminate								
F. Ceratopogonidae	22	32	43	32	22	0	0	7
F. Chaoboridae	0	22	11	11	43	22	32	32
F. Chironomidae	75	151	65	97	172	32	183	129
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda								
Cl. Pelecypoda	215	183	377	258	151	280	269	233
TOTAL NUMBER OF ORGANISMS	409	722	764	632	506	376	571	484
Percent Chironomids	18.42	20.88	8.45		34.03	8.58	32.06	

* lowest practical level

Table 5: Benthic Macroinverte
All values are number per m2

Station	MM-8				MM-9			
Replicate	1*	2	3	Mean	1	2*	3	Mean
P. Coelenterata								
Hydra								
P. Nematoda					86	86	431	201
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma								
P. Annelida								
Cl. Oligochaeta					215	0	603	273
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina					0	86	0	29
O. Harpacticoida								
Cl. Ostracoda					11	0	0	4
O. Amphipoda					344	603	603	517
O. Isopoda								
Cl. Insecta								
O. Coleoptera								
O. Ephemeroptera	86	0	0	29	172	86	517	258
O. Lepidoptera								
O. Megaloptera								
O. Odonata					22	0	0	7
O. Plecoptera								
O. Trichoptera					65	172	0	79
O. Diptera								
indeterminate								
F. Ceratopogonidae	32	291	344	222	183	194	172	183
F. Chaoboridae	603	517	86	402				
F. Chironomidae	205	172	527	301	2164	4133	9989	5429
F. Dolichopodidae								
F. Empididae								
F. Simuliidae								
F. Tabanidae								
F. Tipulidae								
P. Mollusca								
Cl. Gastropoda					54	0	0	18
Cl. Pelecypoda	86	0	258	115				
TOTAL NUMBER OF ORGANISMS	1012	980	1216	1069	3315	5361	12314	6997
Percent Chironomids	20.21	17.58	43.36		65.27	77.11	81.12	

* lowest practical level

Table 5: Benthic Macroinverte

All values are number per m2

Station	MM-10				MM-12			
Replicate	1*	2	3	Mean	1	2	3*	Mean
P. Coelenterata								
Hydra					0	86	0	29
P. Nematoda	65	129	11	68	344	1119	172	545
P. Platyhelminthes								
Cl. Turbellaria								
P. Nemertea								
Prostoma	43	0	0	14	43	0	0	14
P. Annelida								
Cl. Oligochaeta	301	129	108	179	775	603	344	574
Cl. Hirudinea								
P. Arthropoda								
Cl. Arachnida								
O. Hydracarina	86	129	0	72	0	0	86	29
O. Harpacticoida	22	43	0	22				
Cl. Ostracoda	65	43	22	43				
O. Amphipoda					0	0	86	29
O. Isopoda								
Cl. Insecta								
O. Coleoptera	172	431	75	226	43	0	0	14
O. Ephemeroptera	151	0	22	57				
O. Lepidoptera								
O. Megaloptera	0	11	0	4				
O. Odonata	0	11	0	4	0	0	11	4
O. Plecoptera								
O. Trichoptera	65	172	43	93	43	86	0	43
O. Diptera								
indeterminate					344	172	603	373
F. Ceratopogonidae	129	172	22	108	301	431	603	445
F. Chaoboridae								
F. Chironomidae	452	517	97	355	431	517	431	459
F. Dolichopodidae					0	0	258	86
F. Empididae								
F. Simuliidae					0	0	11	4
F. Tabanidae								
F. Tipulidae					0	11	11	7
P. Mollusca								
Cl. Gastropoda	86	43	11	47				
Cl. Pelecypoda	0	0	43	14	301	517	431	416
TOTAL NUMBER OF ORGANISMS	1636	1830	452	1306	2626	3542	3046	3071
Percent Chironomids	27.63	28.23	21.43		16.39	14.59	14.14	

* lowest practical level

Table 6:   Detailed Identification of Benthic Invertebrate Taxa.   May, 2000

Station Replicate	Bicroft Mine BM-LC 3*	BM-1 3*	BM-2 3*	BM-3 2*	BM-4 3*	BM-6 2*	BM-7 3*	BM-8 3*	BM-9 2*	BM-10 2*	BM-11 2*
P. Coelenterata											
Hydra											
P. Nematoda			11	1292		129	11		22		
P. Platyhelminthes											
Cl. Turbellaria											
P. Nemertea											
Prostoma				86							
P. Annelida											
Cl. Oligochaeta											
F. Enchytraeidae											
F. Naididae											
Arcteonais lomondi									22		
Dero digitata							22				
Dero											
Nais variabilis				172							
Slavina appendiculata											
F. Tubificidae											
Aulodrilus piqueti											
Ilyodrilus templetoni											
Limnodrilus hoffmeisteri									97		65
Limnodrilus udekemianus						43					
Rhyacodrilus montana				86							
Tasserkidrilus kessleri											
Tubifex tubifex						43				32	
immatures with hair chaetae				344	129	43			22	32	
immatures without hair chaetae				258		43			11		129
F. Sparganophilidae											
Sparganophilus						65					
Cl. Hirudinea											
F. Glossiphoniidae											
Helobdella stagnalis											
immature											
P. Arthropoda											
Cl. Arachnida											
O. Hydracarina	11			86		22	11			11	22
O. Harpacticoida											
Cl. Ostracoda							22	22		75	11
O. Amphipoda											
F. Crangonyctidae											
Crangonyx											
F. Talitridae											
Hyalella						86		97			
O. Isopoda											
F. Asellidae											
Caecidotea								86			
Cl. Entognatha											
O. Collembola											
Cl. Insecta											
O. Coleoptera											
F. Chrysomelidae											
Donacia				86		11					
F. Dytiscidae											
indeterminate											
F. Elmidae											
Dubiraphia				86		86					
F. Hydrophilidae											
Berosus											
O. Ephemeroptera											

Table 6:   Detailed Identification of Benthic Invertebrate Taxa.   May, 2000

Station	Bicroft Mine BM-LC	BM-1	BM-2	BM-3	BM-4	BM-6	BM-7	BM-8	BM-9	BM-10	BM-11
Replicate	3*	3*	3*	2*	3*	2*	3*	3*	2*	2*	2*
Callibaetis											
F. Caenidae											
Caenis				1206							
F. Ephemeridae											
Ephemera											
Hexagenia			32								
F. Leptophlebiidae											
Leptophlebia				86							
O. Lepidoptera											
F. Pyralidae											
O. Megaloptera											
F. Sialidae											
Sialis											
O. Odonata											
F. Coenagrionidae											
immature				86							
Enallagma											
Ischnura											
F. Corduliidae											
indeterminate											
Epitheca											
F. Gomphidae											
Phanogomphus (=Gomphus)											
indeterminate											
Stylurus											
O. Plecoptera											
?F. Capniidae											
indeterminate											
O. Trichoptera											
F. Hydroptilidae											
Orthotrichia											
Oxyethira				86							
F. Leptoceridae											
Mystacides								11			
Oecetis											
Triaenodes											
F. Limnephilidae											
indeterminate											
F. Philopotamidae											
Chimarra											
F. Phryganeidae											
Agrypnia											
Phryganea											
F. Polycentropodidae											
Nyctiophylax											
Polycentropus											
O. Diptera											
indeterminate											
F. Ceratopogonidae											
indeterminate											
Alluaudomyia											
Bezzia				344			11				
Dasyhelea											
Mallochohelea			22	86		172					
Probezzia											
Serromyia					86						
F. Chaoboridae											
Chaoborus albatus											
Chaoborus flavicans	129	22					258			205	301
Chaoborus punctipennis	1066	743	11				205	22	22	388	657
Chaoborus											
F. Chironomidae											
chironomid pupae				603	86		11	32		43	
S.F. Chironominae											
Aeshum											

Table 6: Detailed Identification of Benthic Invertebrate Taxa. May, 2000

Station	Bicroft Mine										
	BM-LC	BM-1	BM-2	BM-3	BM-4	BM-6	BM-7	BM-8	BM-9	BM-10	BM-11
Replicate	3*	3*	3*	2*	3*	2*	3*	3*	2*	2*	2*
Chironomus		11			301		43		11	86	11
Cladopelma			22	517		129		43			
Cladotanytarsus			11			43		11			
Cryptochironomus											
Cryptotendipes											
Dicrotendipes				86				22			
Einfeldia											
Harnischia											
Glyptotendipes											
Micropsectra											
Microtendipes											
Nilothauma											
Pagastiella								161			
Paralauterborniella			11								
Paratanytarsus											
Paratendipes											
Phaenopsectra											
Polypedilum halterale						86					
Polypedilum scalaenum											
Polypedilum				344							
Pseudochironomus								11			
Stempellina								11			
Stictochironomus			11						65		
Tanytarsus			11	2411		86		75		248	75
Tribelos											
Zavreliella											
T. Chironomini											
T. Tanytarsini											
S.F. Orthocladiinae											
Cricotopus											
Cricotopus/Orthocladius											
Epoicocladius			11								
Eukiefferiella						43					
Heterotrissocladius								11	11		
Nanocladius								22			
Parakiefferiella				86							
Parametriocnemus							11				
Paraphaenocladius											
Psectrocladius											
Smittia											
S.F. Tanypodinae											
Ablabesmyia				689				11			
Clinotanypus						86					
Guttipelopia											
Natarsia					43						
Procladius			11	517		388	86			237	65
Tanypus											
Thienemannimyia complex											
F. Dolichopodidae											
F. Empididae											
Hemerodromia											
F. Simuliidae											
F. Tabanidae											
Chrysops											
F. Tipulidae											
indeterminate											
?Rhabdomastix											
Tipula											
P. Mollusca											
Cl. Gastropoda											
indeterminate											
F. Ancylidae											
Ferrissia				86							
F. Hydrobiidae											

Table 6:   Detailed Identification of Benthic Invertebrate Taxa.   May, 2000

Station	Bicroft Mine BM-LC	BM-1	BM-2	BM-3	BM-4	BM-6	BM-7	BM-8	BM-9	BM-10	BM-11
Replicate	3*	3*	3*	2*	3*	2*	3*	3*	2*	2*	2*
Amnicola			32								
Lyogyrus walkeri											
F. Planorbidae											
Gyraulus deflectus											
Gyraulus											
Helisoma anceps											
?Menetus dilatatus											
F. Valvatidae											
Valvata tricarinata											
F. Viviparidae											
Campeloma decisum											
Cl. Pelecypoda											
F. Sphaeriidae											
Pisidium				86	1033	388			54	11	
Sphaerium rhomboideum											
Sphaerium simile											
Sphaerium striatinum											
F. Unionidae											
Elliptio complanata											
immature											
TOTAL NUMBER OF ORGANISMS	1206	775	194	9817	1679	1970	700	657	312	1389	1335
TOTAL NUMBER OF TAXA	3	3	12	24	5	18	10	16	9	11	9

Table 6: ⊏

| Station
Replicate | Dyno Mine | | | | | | | | | | | | Madawas |
	DM-SC 1*	DM-LC 3*	DM-1 1*	DM-2 1*	DM-3 1*	DM-4 3*	DM-5 2*	DM-6 1*	DM-8 2*	DM-9 3*	DM-10 2*	DM-11 2*	MM-SC 3*
P. Coelenterata													
Hydra													
P. Nematoda	43		86	11			129	258	129				86
P. Platyhelminthes													
Cl. Turbellaria									86			11	
P. Nemertea													
Prostoma													
P. Annelida													
Cl. Oligochaeta													
F. Enchytraeidae													108
F. Naididae													
Arcteonais lom<													
Dero digitata													
Dero						43							
Nais variabilis													43
Slavina append													22
F. Tubificidae													
Aulodrilus pique							388						86
Ilyodrilus templ<				32			980						151
Limnodrilus hof	301							86					
Limnodrilus ude													
Rhyacodrilus m													
Tasserkidrilus k										22		32	
Tubifex tubifex													
immatures with				11			592					32	65
immatures with<	301						495						65
F. Sparganophilid													
Sparganophilus													11
Cl. Hirudinea													
F. Glossiphoniidae													
Helobdella stag													22
immature													
P. Arthropoda													
Cl. Arachnida													
O. Hydracarina			43										22
O. Harpacticoida	129								43				
Cl. Ostracoda												32	
O. Amphipoda													
F. Crangonyctidae													
Crangonyx													
F. Talitridae													
Hyalella							43	86	258		43		
O. Isopoda													
F. Asellidae													
Caecidotea													
Cl. Entognatha													
O. Collembola													
Cl. Insecta													
O. Coleoptera													
F. Chrysomelidae													
Donacia													
F. Dytiscidae													
indeterminate													
F. Elmidae													
Dubiraphia													
F. Hydrophilidae													
Berosus													
O. Ephemeroptera													

Table 6:   C

Station Replicate	Dyno Mine DM-SC 1*	DM-LC 3*	DM-1 1*	DM-2 1*	DM-3 1*	DM-4 3*	DM-5 2*	DM-6 1*	DM-8 2*	DM-9 3*	DM-10 2*	DM-11 2*	Madawas MM-SC 3*
Callibaetis													
F. Caenidae													
Caenis			43				43						22
F. Ephemeridae													
Ephemera													
Hexagenia				11					32				
F. Leptophlebiidae													
Leptophlebia													
O. Lepidoptera													
F. Pyralidae													
O. Megaloptera													
F. Sialidae													
Sialis												11	
O. Odonata													
F. Coenagrionidae													
immature													
Enallagma													
Ischnura													
F. Corduliidae													
indeterminate			11										
Epitheca								22	11				
F. Gomphidae													
Phanogomphus													
indeterminate													
Stylurus													
O. Plecoptera													
?F. Capniidae													
indeterminate													
O. Trichoptera													
F. Hydroptilidae													
Orthotrichia													
Oxyethira	22												
F. Leptoceridae													
Mystacides													
Oecetis									172				
Triaenodes													
F. Limnephilidae													
indeterminate													
F. Philopotamidae													
Chimarra													
F. Phryganeidae													
Agrypnia													
Phryganea													
F. Polycentropodidae													
Nyctiophylax									86				
Polycentropus													
O. Diptera													
indeterminate								172					
F. Ceratopogonidae													
indeterminate													
Alluaudomyia							43						
Bezzia									43				
Dasyhelea								86					22
Mallochohelea			215						86	11			86
Probezzia								86					43
Serromyia													
F. Chaoboridae													
Chaoborus alba													
Chaoborus flavi				54						11			
Chaoborus pun	43			1270								11	
Chaoborus													
F. Chironomidae													
chironomid pup			32		22	43			43	11			22
S.F. Chironominae													
Aeshum			43						172				

Table 6:

Station	Dyno Mine DM-SC	DM-LC	DM-1	DM-2	DM-3	DM-4	DM-5	DM-6	DM-8	DM-9	DM-10	DM-11	Madawas MM-SC
Replicate	1*	3*	1*	1*	1*	3*	2*	1*	2*	3*	2*	2*	3*
Chironomus					75	22						11	
Cladopelma				32			215						
Cladotanytarsu									86				
Cryptochironon							43		43				
Cryptotendipes				32									
Dicrotendipes	172					22			1163				
Einfeldia						22							
Harnischia				11									
Glyptotendipes			43			22			129				
Micropsectra										32		118	
Microtendipes									172				
Nilothauma			43						43				
Pagastiella									301				
Paralauterborni													
Paratanytarsus	431												22
Paratendipes	43		172	11	11		86	258					
Phaenopsectra						43							
Polypedilum ha							172						43
Polypedilum sc				11									
Polypedilum						43		86	86				86
Pseudochirono									215				
Stempellina													
Stictochironom		65								129	301	161	
Tanytarsus	172	22	861	194		301	431	517	258	11		32	86
Tribelos			86			65							
Zavreliella							86	86					
T. Chironomini													
T. Tanytarsini													
S.F. Orthocladiinae													
Cricotopus													
Cricotopus/Orth	43												
Epoicocladius													
Eukiefferiella													
Heterotrissocla													
Nanocladius													
Parakiefferiella													
Parametriocner			86										
Paraphaenocla													65
Psectrocladius													
Smittia													
S.F. Tanypodinae													
Ablabesmyia	86		86										22
Clinotanypus									258				
Guttipelopia	43												
Natarsia													
Procladius		11	172	22			474	172	129				65
Tanypus													
Thienemannim									129				
F. Dolichopodidae													
F. Empididae													
Hemerodromia													
F. Simuliidae													
F. Tabanidae													
Chrysops							32						
F. Tipulidae													
indeterminate													
?Rhabdomastix													
Tipula													
P. Mollusca													
Cl. Gastropoda													
indeterminate													
F. Ancylidae													
Ferrissia													
F. Hydrobiidae													

Table 6:

Station	Dyno Mine DM-SC	DM-LC	DM-1	DM-2	DM-3	DM-4	DM-5	DM-6	DM-8	DM-9	DM-10	DM-11	Madawas MM-SC
Replicate	1*	3*	1*	1*	1*	3*	2*	1*	2*	3*	2*	2*	3*
Amnicola						43			129				
Lyogyrus walke													
F. Planorbidae													
Gyraulus deflec													
Gyraulus	43								43				
Helisoma ance|			11										
?Menetus dilat:													
F. Valvatidae													
Valvata tricarin:													
F. Viviparidae													
Campeloma de								43					
Cl. Pelecypoda													
F. Sphaeriidae													
Pisidium		226		11			86		775				
Sphaerium rho|													
Sphaerium simi			11										86
Sphaerium stri:													
F. Unionidae													
Elliptio complar									11				
immature													
TOTAL NUMBER OF (	1873	323	1798	635	1410	646	4381	1959	5134	226	355	441	1346
TOTAL NUMBER OF 1	14	4	15	13	4	10	17	13	28	6	3	9	23

Table 6:   C

Station Replicate	ka Mine MM-LC 3*	MM-1 1*	MM-2 2*	MM-3 2*	MM-4 1*	MM-5 3*	MM-6 2*	MM-7 1*	MM-8 1*	MM-9 2*	MM-10 1*	MM-12 3*
P. Coelenterata Hydra												
P. Nematoda	75									86	65	172
P. Platyhelminthes Cl. Turbellaria												
P. Nemertea Prostoma				43							43	
P. Annelida												
Cl. Oligochaeta												
F. Enchytraeidae												
F. Naididae												
Arcteonais lom												
Dero digitata												
Dero												
Nais variabilis												
Slavina append												
F. Tubificidae												
Aulodrilus pique												
Ilyodrilus templ								11			151	
Limnodrilus hof	269						32					86
Limnodrilus ude												86
Rhyacodrilus m												
Tasserkidrilus k												
Tubifex tubifex												
immatures with											129	86
immatures with	2906						205	11				86
F. Sparganophilid												
Sparganophilus											22	
Cl. Hirudinea												
F. Glossiphoniida												
Helobdella stag			11									
immature												
P. Arthropoda												
Cl. Arachnida												
O. Hydracarina	11	11					43	11		86	86	86
O. Harpacticoida											22	
Cl. Ostracoda	43					75	32	75			65	
O. Amphipoda												
F. Crangonyctida												
Crangonyx												
F. Talitridae												
Hyalella				86	172		22	11		603		86
O. Isopoda												
F. Asellidae												
Caecidotea												
Cl. Entognatha												
O. Collembola											22	
Cl. Insecta												
O. Coleoptera												
F. Chrysomelidae												
Donacia												
F. Dytiscidae												
indeterminate												
F. Elmidae												
Dubiraphia				474							172	
F. Hydrophilidae												
Berosus				86								
O. Epherneroptera												

	ka Mine											
Station	MM-LC	MM-1	MM-2	MM-3	MM-4	MM-5	MM-6	MM-7	MM-8	MM-9	MM-10	MM-12
Replicate	3*	1*	2*	2*	1*	3*	2*	1*	1*	2*	1*	3*
Callibaetis												
F. Caenidae												
Caenis				43	344				86	86	151	
F. Ephemeridae												
Ephemera					194							
Hexagenia												
F. Leptophlebiidae												
Leptophlebia												
O. Lepidoptera												
F. Pyralidae				43								
O. Megaloptera												
F. Sialidae												
Sialis					108							
O. Odonata												
F. Coenagrionidae												
immature												
Enallagma												
Ischnura												
F. Corduliidae												
indeterminate												
Epitheca												
F. Gomphidae												
Phanogomphus												11
indeterminate												
Stylurus				129								
O. Plecoptera												
?F. Capniidae												
indeterminate												
O. Trichoptera												
F. Hydroptilidae												
Orthotrichia												
Oxyethira												
F. Leptoceridae												
Mystacides												
Oecetis												
Triaenodes											65	
F. Limnephilidae												
indeterminate												
F. Philopotamidae												
Chimarra												
F. Phryganeidae												
Agrypnia										172		
Phryganea												
F. Polycentropodidae												
Nyctiophylax												
Polycentropus												
O. Diptera												
indeterminate												603
F. Ceratopogonidae												
indeterminate												
Alluaudomyia												
Bezzia										108	43	86
Dasyhelea				1335						86		
Mallochohelea				129	172			22	22		86	517
Probezzia							32		11			
Serromyia												
F. Chaoboridae												
Chaoborus alba									603			
Chaoborus flavi	11	75	97			11	22	43				
Chaoborus pun												
Chaoborus												
F. Chironomidae												
chironomid pup	97		97		86					517	65	86
S.F. Chironominae												
Aeshum												

Table 6: C

ka Mine

| Station | MM-LC | MM-1 | MM-2 | MM-3 | MM-4 | MM-5 | MM-6 | MM-7 | MM-8 | MM-9 | MM-10 | MM-12 |
Replicate	3*	1*	2*	2*	1*	3*	2*	1*	1*	2*	1*	3*
Chironomus	161	129	517			11	151	161	32			
Cladopelma									86			
Cladotanytarsu										1550		
Cryptochironon											43	
Cryptotendipes												
Dicrotendipes										344		
Einfeldia												
Harnischia												
Glyptotendipes												
Micropsectra												
Microtendipes					86							
Nilothauma												
Pagastiella										258	22	
Paralauterborni												
Paratanytarsus											129	
Paratendipes											22	
Phaenopsectra					86							
Polypedilum ha										86	22	
Polypedilum sc												
Polypedilum					86					86	22	
Pseudochirono												
Stempellina												
Stictochironom												
Tanytarsus	151		11		947					86	65	86
Tribelos												
Zavreliella												
T. Chironomini												
T. Tanytarsini												
S.F. Orthocladiinae												
Cricotopus				43								
Cricotopus/Orth										517		
Epoicocladius												
Eukiefferiella												
Heterotrissocla												
Nanocladius												
Parakiefferiella										172		
Parametriocner												
Paraphaenocla												
Psectrocladius												172
Smittia												86
S.F. Tanypodinae												
Ablabesmyia										431		
Clinotanypus												
Guttipelopia												
Natarsia												
Procladius	97		11	43	517			11	86	86	65	
Tanypus	388	43	43			431						
Thienemannim					86							
F. Dolichopodidae												258
F. Empididae												
Hemerodromia												
F. Simuliidae												11
F. Tabanidae												
Chrysops												
F. Tipulidae												
indeterminate												
?Rhabdomastix												11
Tipula												

P. Mollusca
  Cl. Gastropoda
    indeterminate
    F. Ancylidae
    Ferrissia
    F. Hydrobiidae

Table 6:   □

Station	MM-LC	MM-1	MM-2	MM-3	MM-4	MM-5	MM-6	MM-7	MM-8	MM-9	MM-10	MM-12
Replicate	3*	1*	2*	2*	1*	3*	2*	1*	1*	2*	1*	3*
Amnicola				43							86	
Lyogyrus walke												
F. Planorbidae												
Gyraulus deflec												
Gyraulus												
Helisoma ance;				11								
?Menetus dilata												
F. Valvatidae												
Valvata tricarina												
F. Viviparidae												
Campeloma de												
Cl. Pelecypoda												
F. Sphaeriidae												
Pisidium				301	86		183	151	86			431
Sphaerium rhor												
Sphaerium simi												
Sphaerium stria				118								
F. Unionidae												
Elliptio complar												
immature												
TOTAL NUMBER OF (	4209	258	786	2928	2971	527	721	506	1012	5360	1658	3046
TOTAL NUMBER OF 1	10	4	6	15	12	4	9	10	8	17	23	18

TABLE 7. Mean (± s.d.) water quality characteristics in Bancroft 2000 sediment bioassays.

a

Test Organism: Mayfly (*Hexagenia limbata*)   Test Temperature: 20°C

Station	pH	D.O. mg/L	Conductivity umho/cm	Total Ammonia mg/L	Un-ionized Ammonia mg/L
Control	7.77 (.18)	9.1 (0.2)	246 (3)	0.11 (0.02)	<0.003
BM-LC Reference	6.51 (1.44)	9.1 (0.2)	220 (27)	0.11 (0.03)	<0.003
	D-20 4.93				
MM-2	7.78 (.55)	9.1 (0.2)	526 (72)	0.50 (0.48)	<u>0.033</u>
MM-5	7.64 (.67)	8.9 (0.1)	623 (87)	0.98 (0.67)	<u>0.043</u>
MM-7	6.68 (1.30)	9.0 (0.2)	388 (71)	0.11 (0.02)	<0.003
	D-20 4.88				
MM-9	8.05 (.06)	9.1 (0.3)	313 (29)	0.44 (0.15)	0.016
DM-2	7.27 (.62)	9.2 (0.1)	302 (29)	0.14 (0.05)	<0.003
DM-3	4.95 (1.90)	9.0 (0.3)	404 (110)	0.53 (0.11)	0.005
	D-20 3.74				
DM-4	7.52 (.37)	9.1 (0.2)	263 (29)	0.54 (0.21)	0.008
BM-6	8.04 (.01)	8.9 (0.3)	323 (44)	0.38 (0.34)	0.014
BM-7	6.48 (1.43)	9.1 (0.1)	276 (29)	0.16 (0.07)	<0.003
	D-20 4.97				

b

Test Organism: Midge (*Chironomus tentans*)   Test Temperature: 20°C

Station	pH	D.O. mg/L	Conductivity umho/cm	Total Ammonia mg/L	Un-ionized Ammonia mg/L
Control	7.66 (.02)	8.5 (0.4)	273 (16)	0.22 (0.04)	<0.003
BM-LC Reference	7.20 (.01)	8.0 (0.6)	210 (5)	0.32 (0.04)	<0.003
MM-2	8.00 (.12)	8.6 (0.6)	527 (8)	1.50 (0.56)	<u>0.057</u>
MM-5	8.05 (.03)	8.6 (0.4)	612 (30)	2.35 (0.21)	<u>0.089</u>
MM-7	7.69 (.12)	8.6 (0.1)	367 (39)	0.75 (0.49)	0.011
MM-9	7.93 (.00)	8.3 (0.3)	312 (22)	1.20 (0.70)	<u>0.045</u>
DM-2	7.57 (.03)	8.6 (0.3)	299 (19)	0.85 (0.35)	0.010
DM-3	7.34 (.13)	8.1 (0.4)	298 (37)	1.25 (0.63)	0.011
DM-4	7.70 (.07)	8.4 (0.5)	273 (8)	1.30 (0.70)	<u>0.032</u>
BM-6	8.00 (.09)	8.1 (0.5)	312 (23)	1.40 (0.70)	<u>0.053</u>
BM-7	7.39 (.07)	8.5 (0.6)	259 (10)	0.28 (0.16)	<0.003

a Sample size N=4; b Sample size N=3;

Underlining indicates un-ionized ammonia concentrations that exceed the PWQO of 0.02 mg/L

TABLE 7. Mean (± s.d.) water quality characteristics in Bancroft 2000 sediment bioassays.

				Total	Un-ionized
Test Organism: Minnow (*Pimephales promelas*)				Test Temperature: xx.x°C (x.x)[b]	
Station	pH	D.O. mg/L	Conductivity umho/cm	Ammonia mg/L	Ammonia mg/L
Control	7.17 (0.67)	8.9 (0.2)	292 (25)	0.29 (0.13)	0.004
BM-LC Reference	6.81 (0.47)	8.6 (0.3)	215 (35)	3.82 (3.19)	0.007
MM-2	7.17 (0.52)	8.0 (0.3)	658 (164)	5.22 (3.76)	<u>0.024</u>
MM-5	6.01 (1.27) D-20 5.19	7.6 (0.5)	1101 (480)	4.95 (3.42)	0.016
MM-7	5.87 (1.22) D-20 4.70	6.7 (1.7)	653 (282)	4.28 (3.95)	<0.003
MM-9	7.51 (0.27)	7.8 (1.0)	384 (91)	4.46 (3.81)	<u>0.039</u>
DM-2	6.69 (0.53)	8.2 (0.6)	368 (78)	2.87 (1.97)	0.004
DM-3	6.59 (1.21) D-7 5.73	7.0 (0.1)	576 (406)	1.20 (0.70)	0.004
DM-4	7.32 (0.19)	8.4 (0.5)	303 (74)	4.26 (3.97)	<u>0.037</u>
BM-6	7.65 (0.13)	8.0 (0.1)	364 (63)	4.60 (3.65)	<u>0.106</u>
BM-7	6.25 (0.55) D-20 5.96	8.3 (0.4)	358 (123)	3.99 (3.72)	<0.003

a Sample size N=4; b Sample size N=3;
Underlining indicates un-ionized ammonia concentrations that exceed the PWQO of 0.02 mg/L

TABLE 8. Sediment physical and nutrient characteristics in control(s) and Bancroft 2000 sediment
used in sediment bioassays.

Station	% Sand (2mm-62um)	% Silt (62-3.7um)	% Clay (3.7-0.1um)	% LOI	TOC mg/g	TP mg/g	TKN mg/g
Honey Harbour Control	7.0	64.9	27.9	6.8	32	1.0	3.5
Reference Station BM-LC	2.0 <T	81.9	16.7	35.0	180	1.8	12.0
Bancroft Station MM - 2	13.0	75.0	11.8	40.0	190	1.5	15.0
Station MM - 5	8.0	68.7	23.5	25.0	110	1.6	6.8
Station MM - 7	14.0	68.1	17.9	35.0	180	1.4	11.0
Station MM - 9	29.0	64.2	7.3	59.0	290	0.6	18.0
Station DM - 2	1 < W	67.8	31.2	4.2	18	0.5	1.3
Station DM - 3	1 < W	67.2	30.6	19.0	72	0.8	4.0
Station DM - 4	12.0	74.7	13.1	46.0	220	1.1	17.0
Station BM - 6	52.0	40.8	6.9	10.0	50	0.8	3.7
Station BM - 7	8.0	73.9	18.7	29.0	140	1.9	9.1
PSQG SEL Conc (mg/g dry weight)					100	2.0	4.8

<W - Not Detected; <T - Trace Amount Measured; Shading indicate sediment nutrient concentrations that exceed PSQG-LELs.

TABLE 9. Bulk concentrations of trace metals in control(s) and Bancroft 2000 sediment (µg/g dry weight) used in sediment bioassays.

Station	Al %	As	Cd	Cr	Cu	Fe %	Hg	Mn	Ni	Pb	St	Ur	Zn
Honey Harbour													
Control	2.0	5.0	1.1	41	19	3.3	0.06	920	30	39	33	NA	130
Reference													
Stn BM - LC	1.2	7.9	2.0	18	27	2.0	0.24	330	13	76	58	5.5	150
Bancroft													
Stn MM - 2	0.8	7.4	3.7	18	46	4.2	0.15	1300	57	86	280	100	200
Stn MM - 5	1.6	6.7	2.8	21	52	15.0	0.10	1100	29	180	160	540	140
Stn MM - 7	1.1	11.0	3.6	24	62	12.0	0.18	1400	45	120	200	474	220
Stn MM - 9	0.6	2.2	2.3	16	35	5.3	0.11	700	28	31	160	181	140
Stn DM - 2	1.1	5.5	1.2	28	55	5.5	0.09	430	19	300	19	78	80
Stn DM - 3	0.6	6.6	2.5	14	31	14.0	0.11	790	27	200	42	117	100
Stn DM - 4	0.9	4.3	3.9	11	50	4.0	0.19	400	65	250	38	282	250
Stn BM - 6	0.8	2.3	0.9 <T	16	22	2.1	0.07	370	12	53	52	491	120
Stn BM - 7	1.5	12.0	3.0	23	31	4.0	0.27	1000	20	94	51	83	310
PSQG SEL Conc.	NA	33	10	110	110	4.0	2.0	1100	75	250	NA	NA	820
PSQG LEL Conc.	NA	6.0	0.6	26	16	2.0	0.2	460	16	31	NA	NA	120

NA - Not Available; <W - Not Detected; <T - Trace Amount; Underlining indicate sediment trace metal concentrations that exceed PSQG-LELs.
Shading indicate sediment trace metal concentrations that exceed PSQG-SELs.

TABLE 10: Summary of biological results on mayfly, midge and minnow sediment bioassays for control(s) and Bancroft 2000 sediments.

Mean values (± standard deviation) where sample size n=3 reps for mayfly, midge and minnow tests.

Test Organism / Station	Mayfly *Hexagenia limbata* % Mortality	Ave. Individual Body Weight (mg wet wt.)	Midge *Chironomus tentans* % Mortality	Ave. Individual Body Weight (mg wet wt.)	Fathead Minnow *Pimephales promelas* % Mortality
Honey Harbour Control	A 6.6 (6)	D 6.39 (0.4)	A 15.5 (8)	ABC 7.79 (1.2)	A 0 (0)
Reference Station BM - LC	BC 26.6 (11)	CD 8.68 (1.5)	A 2.2 (4)	E 4.72 (0.4)	A 3.3 (6)
Bancroft Station MM - 2	AB 10.0 (0)	A 16.03 (0.9)	A 4.4 (7)	A 9.59 (0.6)	A 0 (0)
Station MM - 5	C * 40.0 (10)	D 6.29 (1.6)	A 8.8 (5)	BCDE 6.00 (1.7)	A 16.6 (15)
Station MM - 7	ABC 23.3 (6)	D 7.74 (0.6)	A 0 (0)	AB 8.78 (2.1)	A 33.3 (60)
Station MM - 9	BC 26.6 (21)	D 8.33 (2.3)	A 13.3 (7)	A 9.29 (0.9)	A 0 (0)
Station DM - 2	AB 20.0 (10)	D 7.52 (2.3)	A 6.6 (11)	DE 5.66 (1.0)	A 3.3 (6)
Station DM - 3	E ** 100 (0)	-	A 8.8 (4)	BCD 6.83 (2.4)	B ** 100 (0)
Station DM - 4	ABC 23.3 (15)	AB 14.37 (3.0)	A 11.0 (4)	BCDE 6.47 (0.4)	A 3.3 (6)
Station BM - 6	D ** 63.3 (6)	-	A 4.4 (8)	CDE 5.92 (2.2)	A 0 (0)
Station BM - 7	AB 10.0 (10)	BC 12.17 (1.0)	A 8.8 (4)	AB 8.02 (0.6)	A 0 (0)
% MSD	25.2	-	15.1	-	44.0
% C.V.	25.6	22.2	77.9	17.3	57.6
D.P.	10.2	5.1	2.5	4.0	11.1

** %Mortality value is significantly different than the negative and reference control sediments (Dunnett's 1-tailed t-test; $p<0.05$).

* %Mortality value is significantly different than the negative control only (Dunnett's 1-tailed t-test; $p<0.05$).

A Means sharing a common letter within a column are not significantly different; Tukey's HSD test or LSD t-test for % Mortality ($p<0.05$) and planned comparisons using LSMEANS for comparing Body Weight ($p<0.01$).

MSD - Minimum Significant Difference; C.V. - Coefficient of Variation; D.P. - Discriminatory Power.

TABLE 11. Bulk concentrations of chlorinated organics and pesticides in Bancroft 2000 sediment (ng/g dry weight) used in sediment bioassays.

All Stations	Total PCBs	20 <W
	Heptachlor	1 <W
(exceptions listed below)	Aldrin	1 <W
	Mirex	5 <W
	a-BHC	1 <W
	b-BHC	1 <W
	a-Chlordane	2 <W
	g-Chlordane	2 <W
	op-DDT	5 <W
	pp-DDD	5 <W
	pp-DDT	5 <W
	Oxychlordane	5 <W
	Methoxychlor	5 <W
	Heptachlor epoxide	1 <W
	Endosulphan I	2 <W
	Dieldrin	2 <W
	Endrin	4 <W
	Endosulphan II	4 <W
	Endosulphan sulphate	4 <W
	Hexachlorobutadiene	1 <W
	Octachlorostyrene	1 <W
	123-Trichlorobenzene	2 <W
	135-Trichlorobenzene	2 <W
	1234-Tetrachlorobenzene	1 <W
	1235-Tetrachlorobenzene	1 <W
	1245-Tetrachlorobenzene	1 <W
	Hexachloroethane	1 <W
	Pentachlorobenzene	1 <W
	236-Trichlorotoluene	1 <W
	245-Trichlorotoluene	1 <W
Station BM - LC	pp - DDE	3 <T
	g - BHC	3 <T
	Hexachlorobenzene	3 <T
Station MM - 9	124-Trichlorobenzene	4 <T
Station DM - 3	124-Trichlorobenzene	4 <T

<W - Not Detected.

TABLE 12. Mean metal concentrations in fathead minnows exposed to control(s) and Bancroft 2000 sediments in the laboratory and associated biota-sediment accumulation factors (BSAFs).

Tissue concentrations reported as µg/g wet weight; Mean values ± standard deviation; Sample size n=3.

Station	Minnow Uranium (ug/g wet weight)		BSAF (tissue/sediment dry wt)
Pre-exposure	0.01 (0.0)	<W	
Honey Harbour Control	0.01 (.01)	A <W	
Reference Station BM - LC	0.03 (.01)	A <T	0.03
Station MM - 2	0.41 (.14)	BC	0.03
Station MM - 5	0.36 (.05)	B	0.004
Station MM - 7	0.35 (.05)	B	0.004
Station MM - 9	0.74 (.19)	D	0.02
Station DM - 2	0.61 (.15)	CD	0.05
Station DM - 4	2.59 (.20)	E	0.06
Station BM - 6	39.77 (6.61)	F	0.53
Station BM - 7	0.45 (.04)	BC	0.03

A Means sharing a common letter within a column are not significantly different using LSD t-test (p<0.05)

TABLE 13. Spatial variability in sediment toxicity and uranium uptake for Bancroft 2000 samples.

Station	Sediment Parameters Exceeding PSQG SELs	Uranium Tissue Relative to Reference	Sediment Uranium (ug/g, dw)	Mayfly Lethality	Mayfly Growth	Midge Lethality	Midge Growth	Minnow Lethality
Stn BM - LC	TOC, TKN		5	N	N	N	T	N
Stn MM - 2	TOC, TKN Fe, Mn	13 X	100	N	N	N	N	N
Stn MM - 5	TOC, TKN Fe, Mn	12 X	540	N	N	N	N	N
Stn MM - 7	TOC, TKN Fe, Mn	11 X	474	N	N	N	N	N
Stn MM - 9	TOC, TKN Fe	24 X	181	N	N	N	N	N
Stn DM - 2	Fe, Pb	20 X	78	N	N	N	N	N
Stn DM - 3	Fe	N/A	117	T	-	N	N	T
Stn DM - 4	TOC, TKN Fe, Pb	86 X	282	N	N	N	N	N
Stn BM - 6		1323 X	491	T	-	N	N	N
Stn BM - 7	TOC, TKN Fe	15 X	83	N	N	N	N	N

N - Not Toxic, % mortality less than reference control and p>0.05; p>0.10 for growth data;
T - Toxic, % mortality greater than reference control and p<0.05; p<0.10 for growth data.
N/A - Not Available.

Figures

Figure 1
Bancroft Uranium Mines:
Study Area

Madawaska Mine

Bow L.

Bicroft Mine

Inlet Bay

Paudash L.

Lower Paudash L.

Canadian Dyno Mine

Farm L.

1000   0   1000   2000   Meters

Ontario
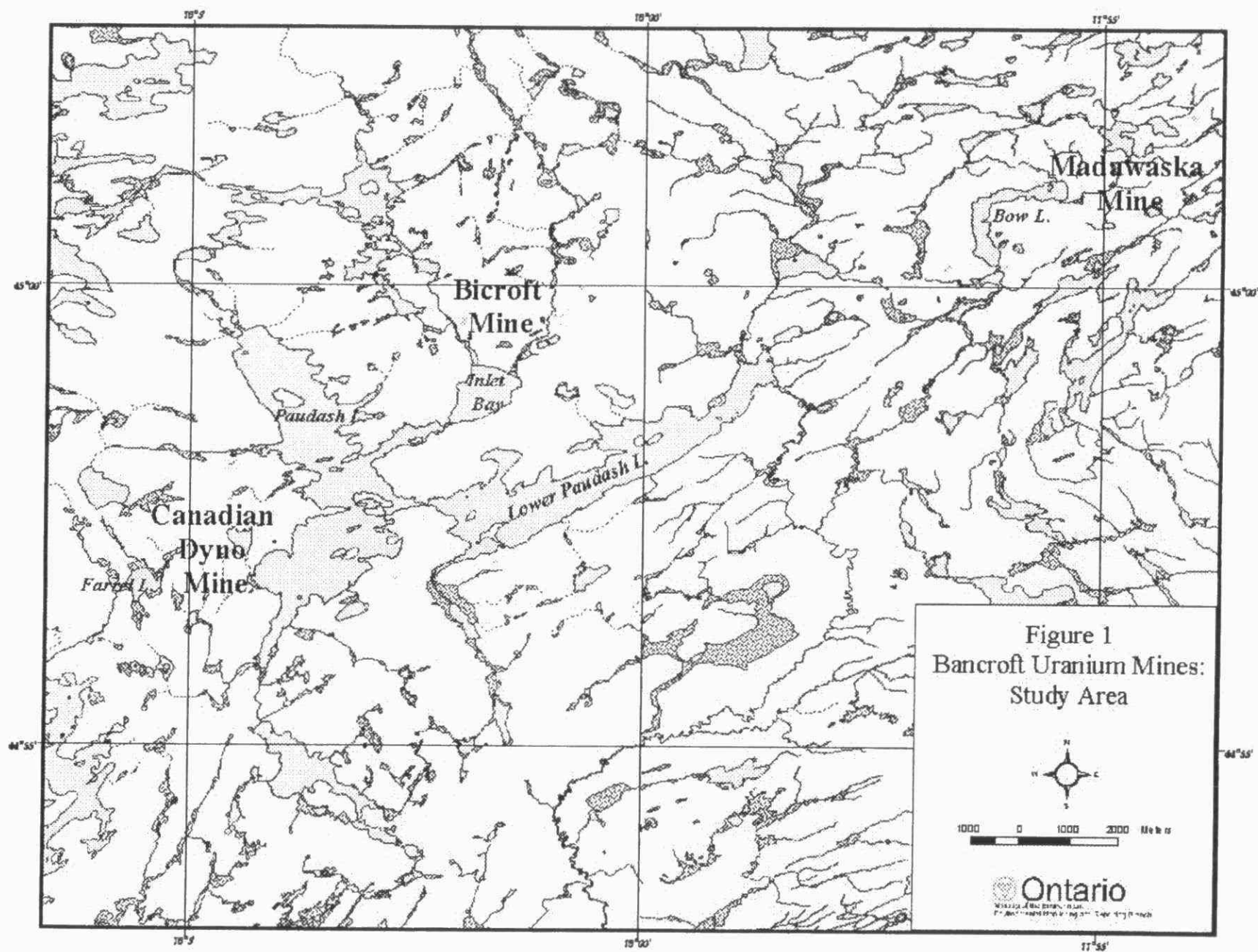
Figure 2
Location of Proposed Sampling Sites
Madawaska Mine
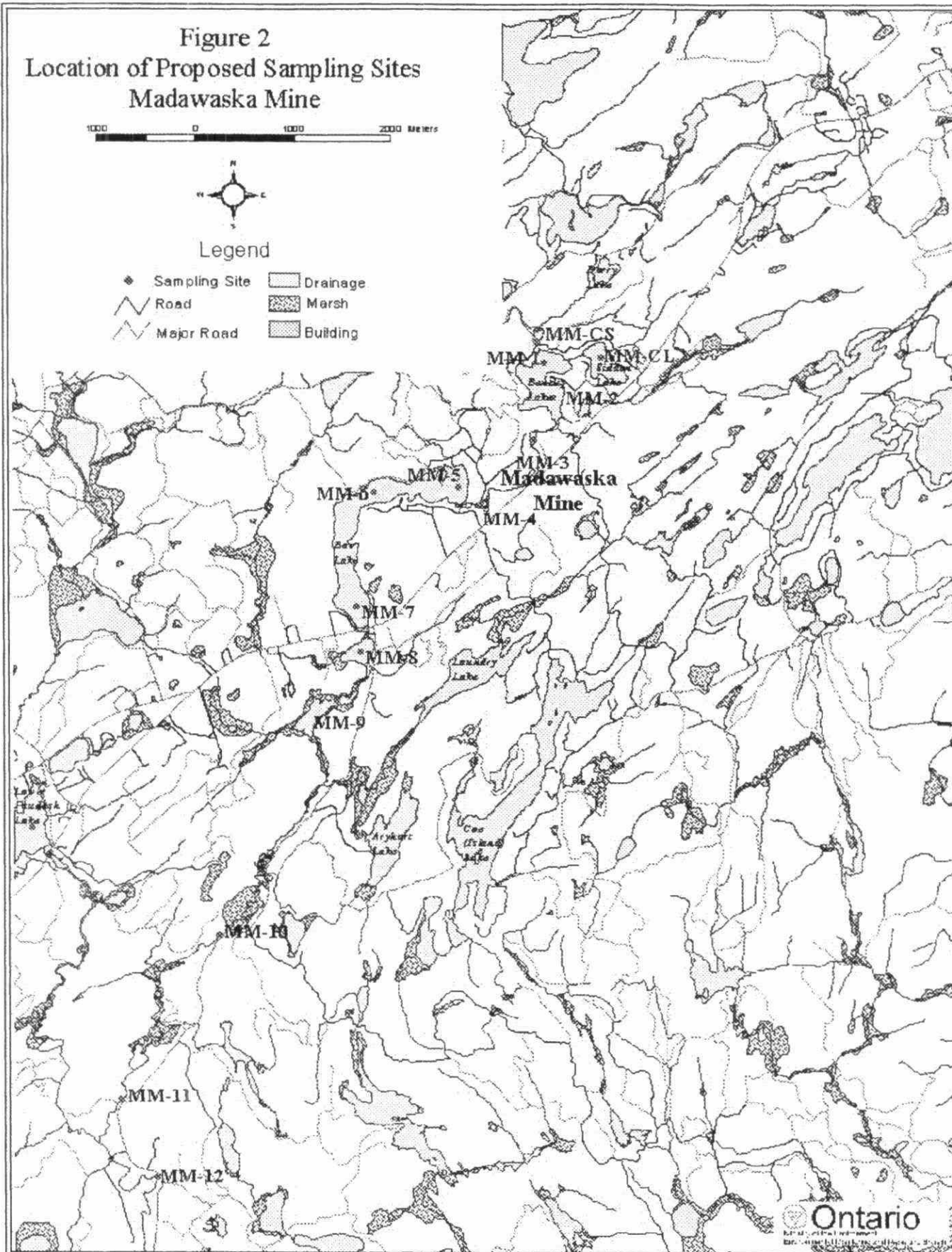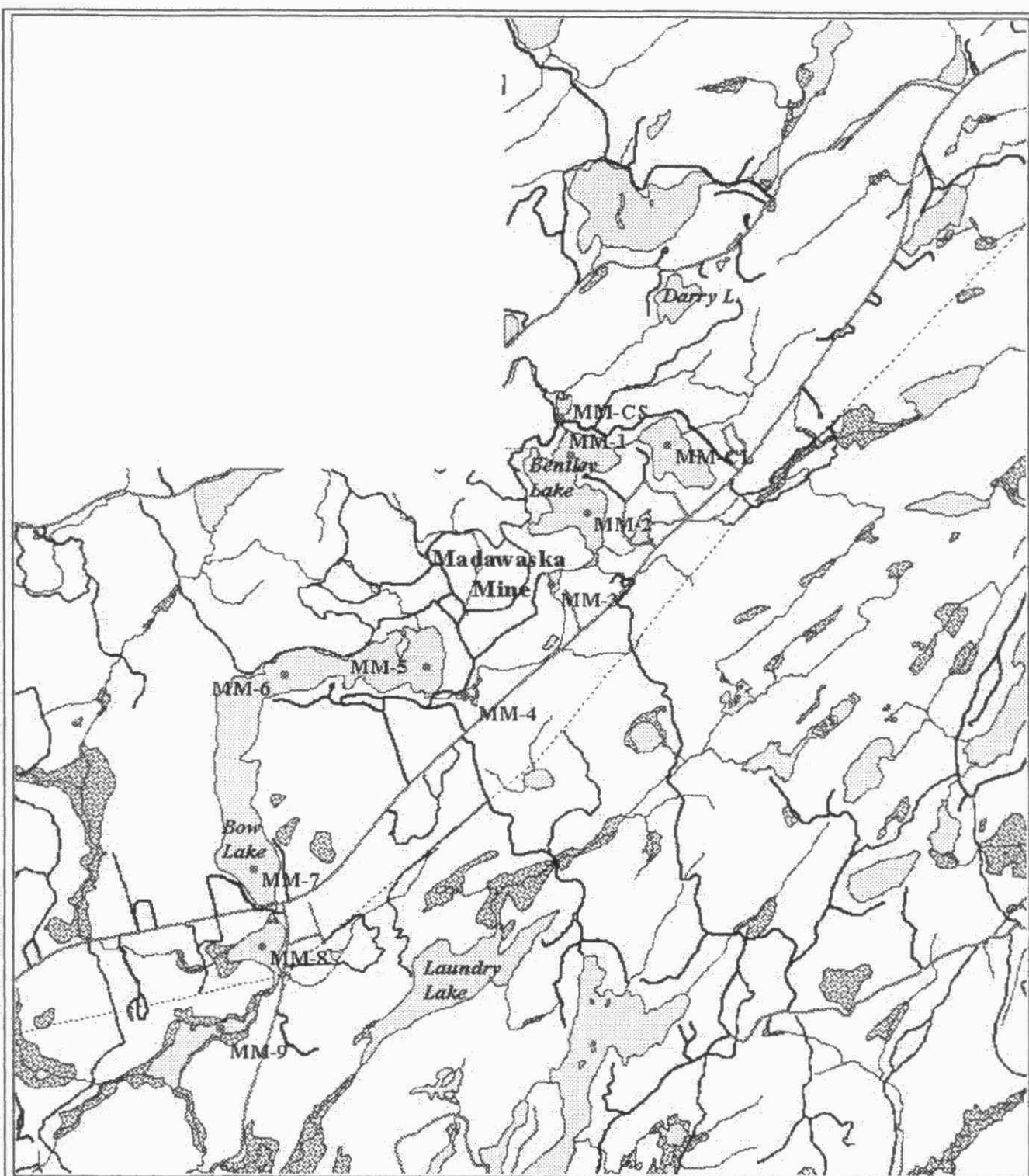
Figure 3
Detail of Proposed Sampling Sites
Madawaska Mine

Sampling Station
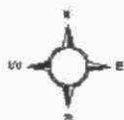
Figure 4
Locations of Bancroft Sampling Sites
Bicroft and Dyno Mines
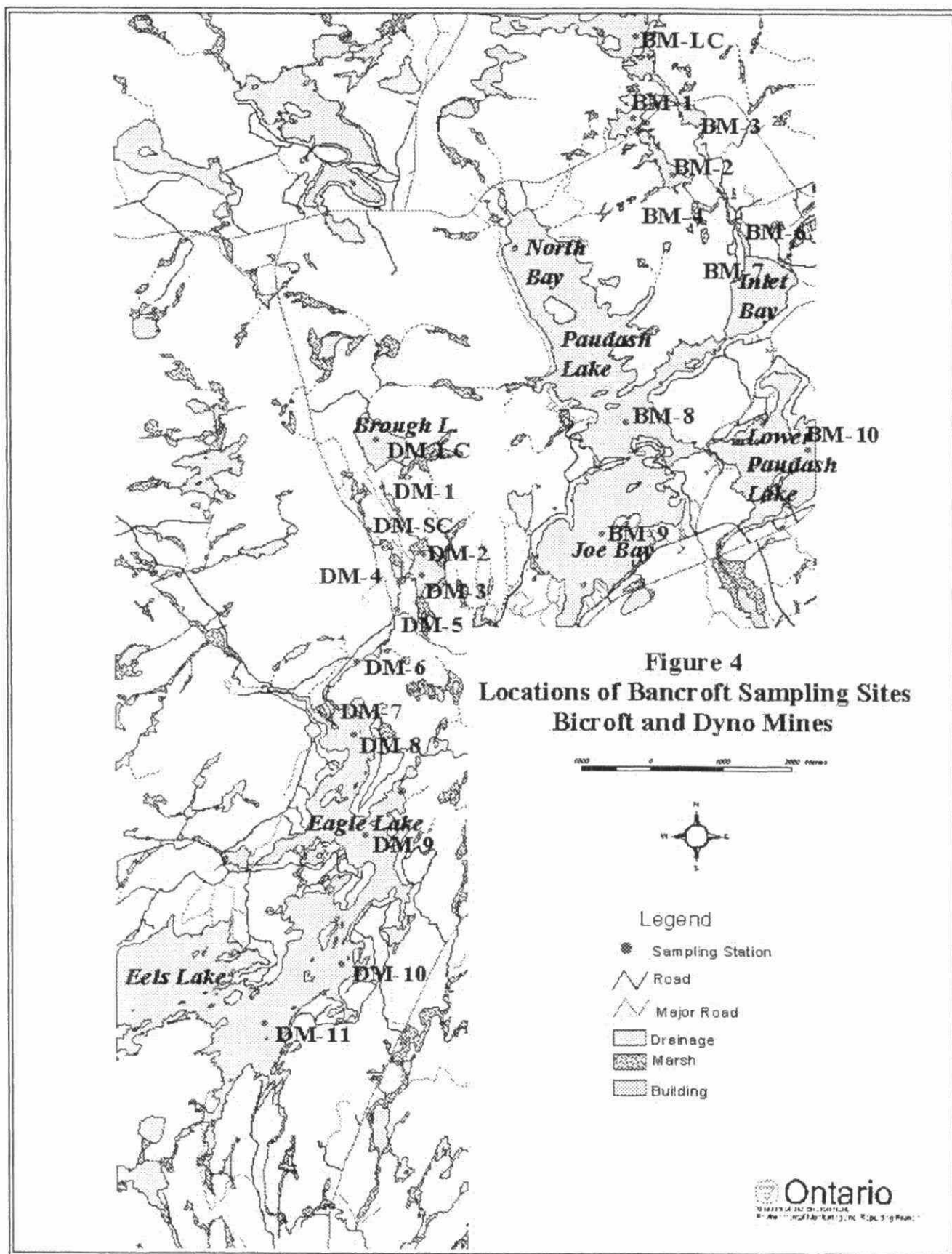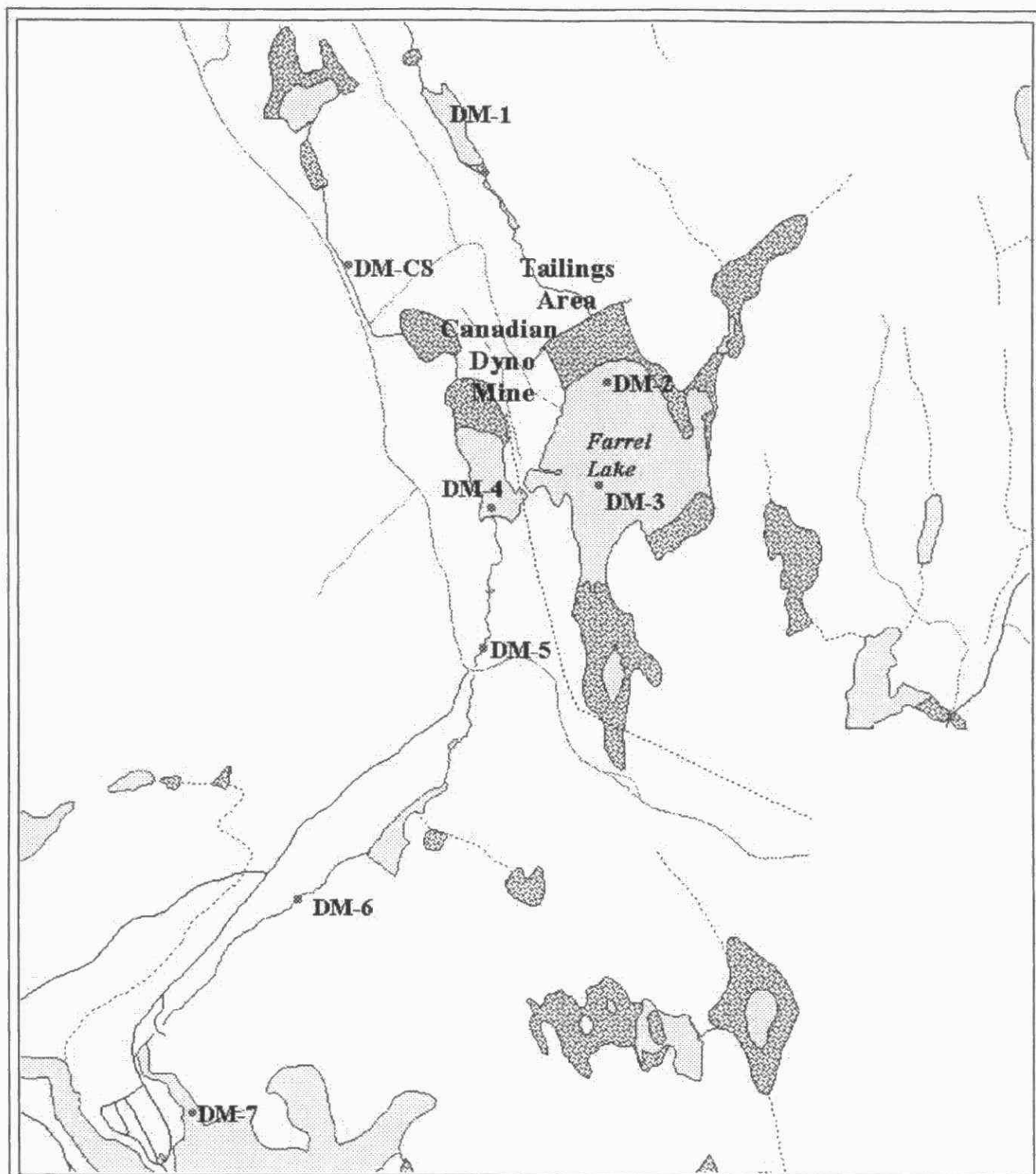
Figure 5
Detail of Proposed Sampling Sites
Canadian Dyno Mine

* Sampling Station

Ontario
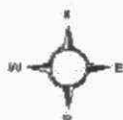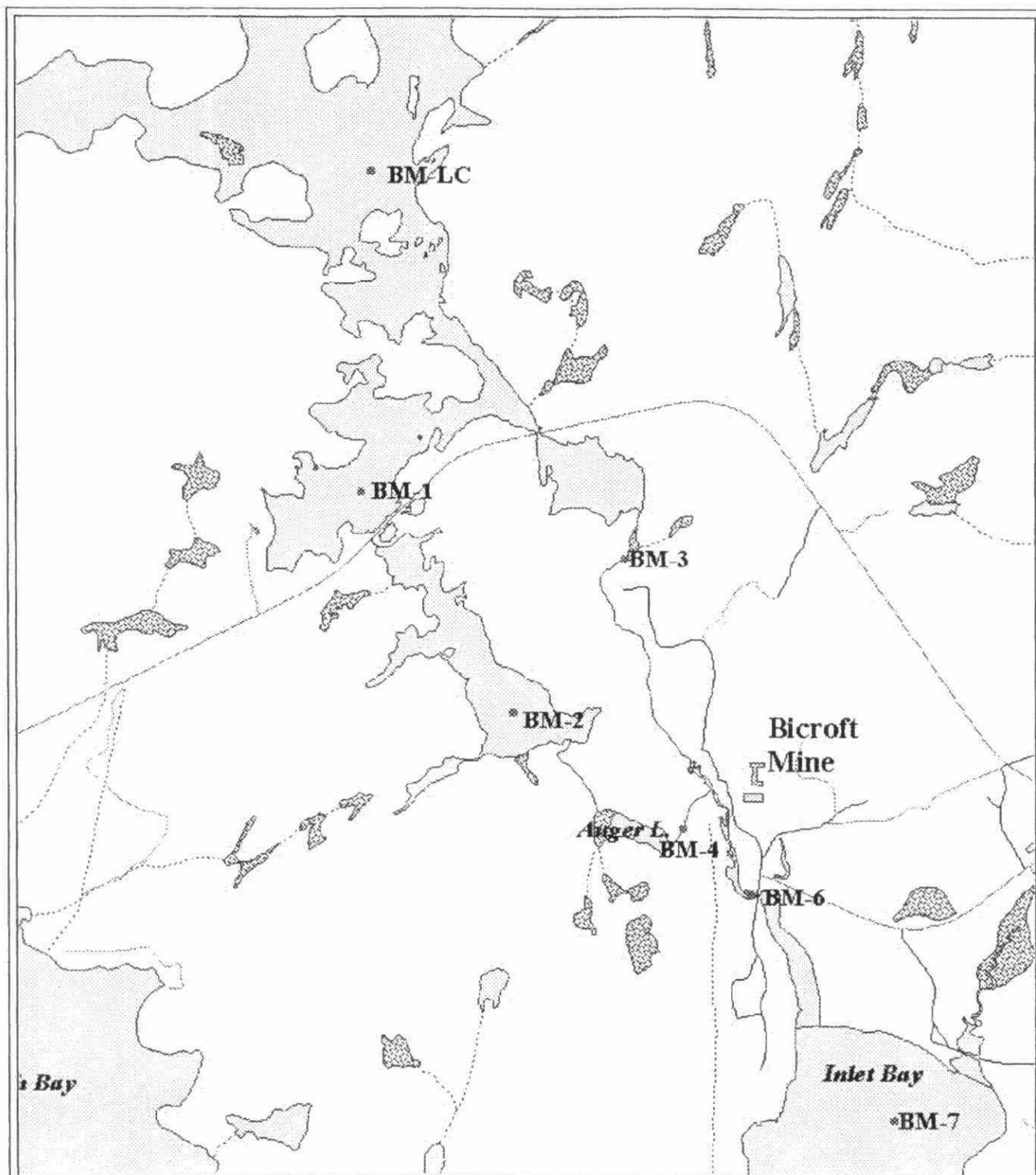
Figure 6
Detail of Proposed Sampling Sites
Bicroft Mine

❋ Sampling Station

Figure 7: Bicroft Mine Site. Extent of Tailings area, 1965.
(Deputy Ministers' Report, 1965)
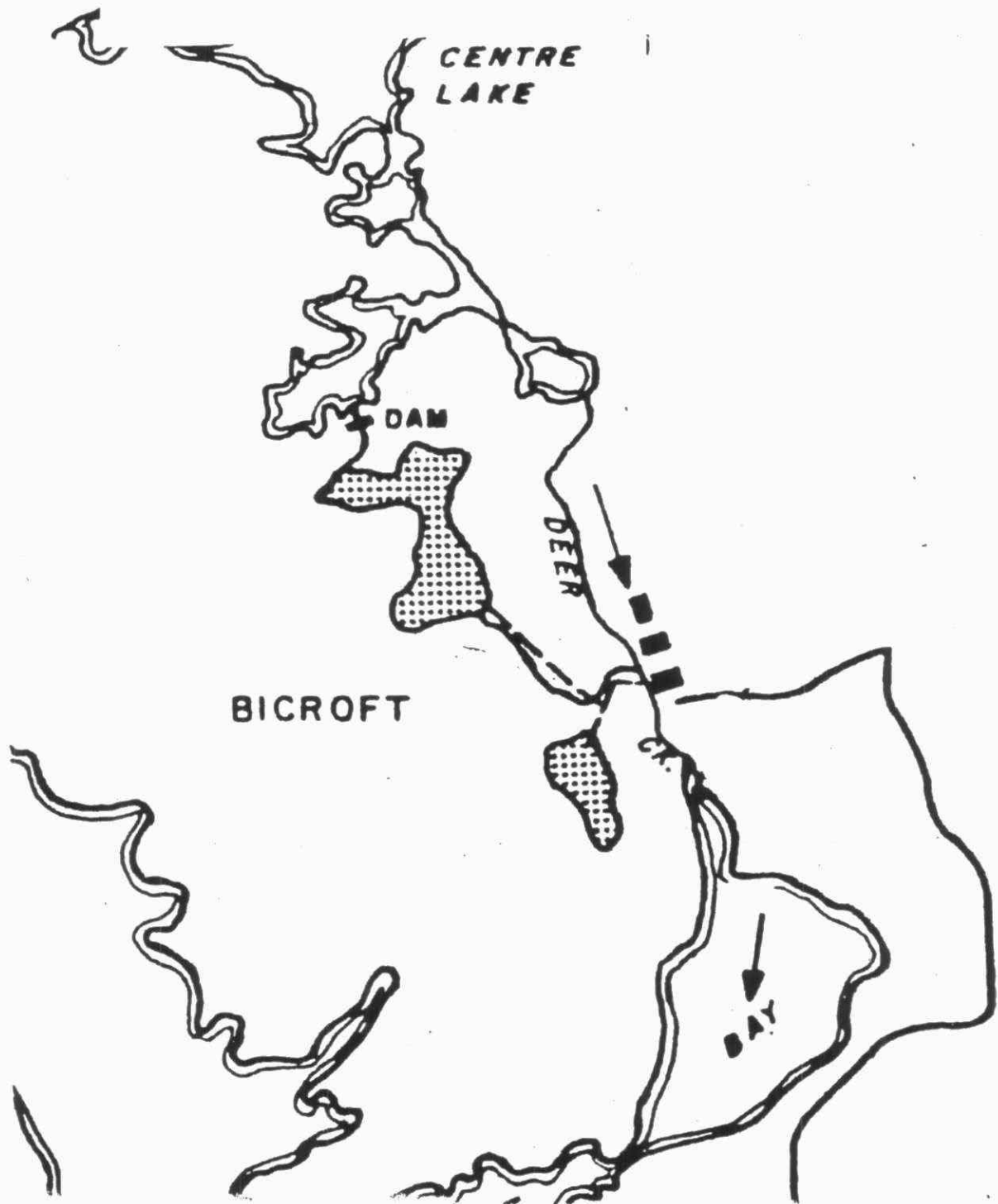
Figure 8: Canadian Dyno Mine. Extent of Tailings Area, 1965
(Deputy Ministers' Report, 1965)

DYNO

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LAR

28
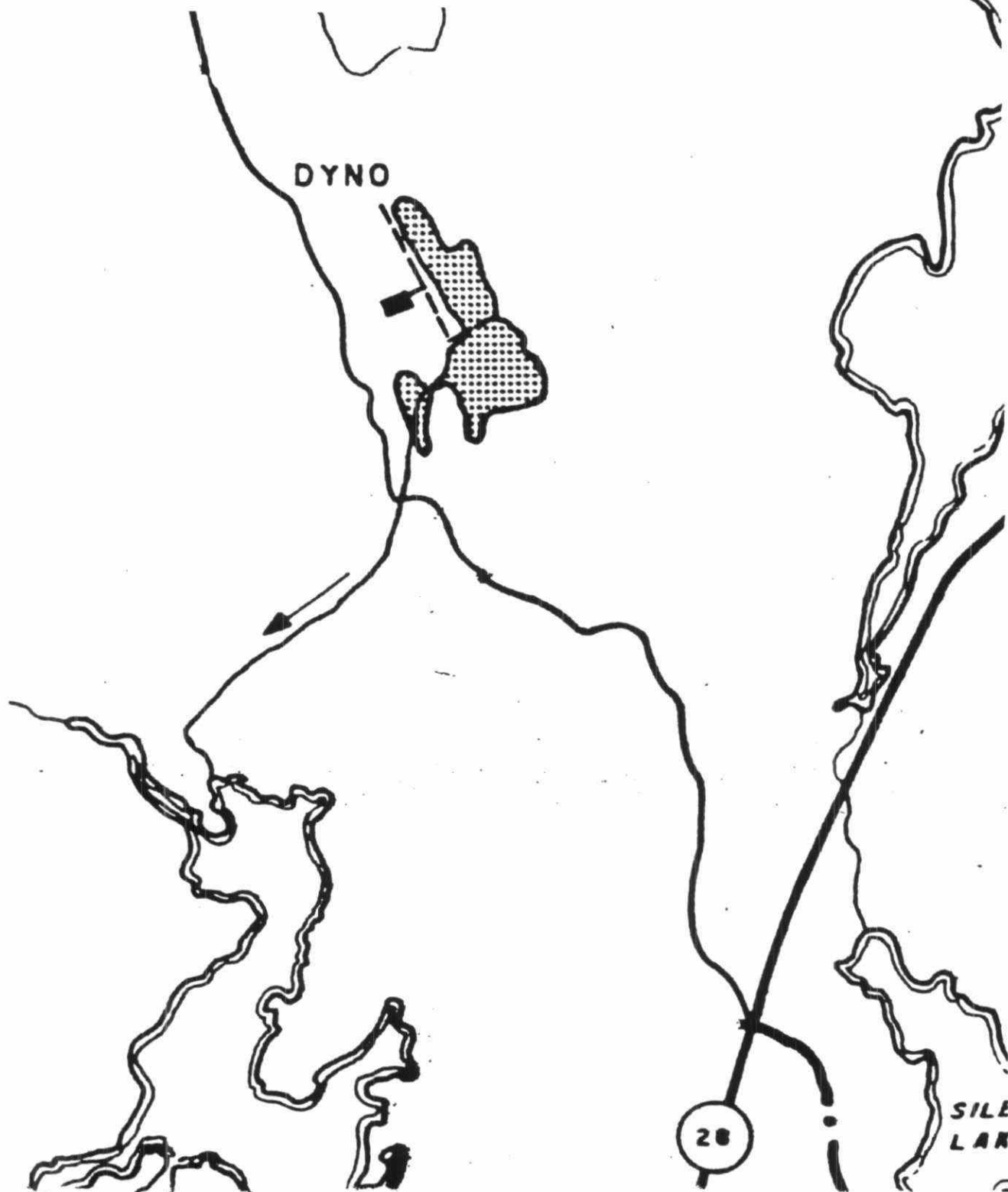
Figure 9a: Conductivity in Water, May 2000
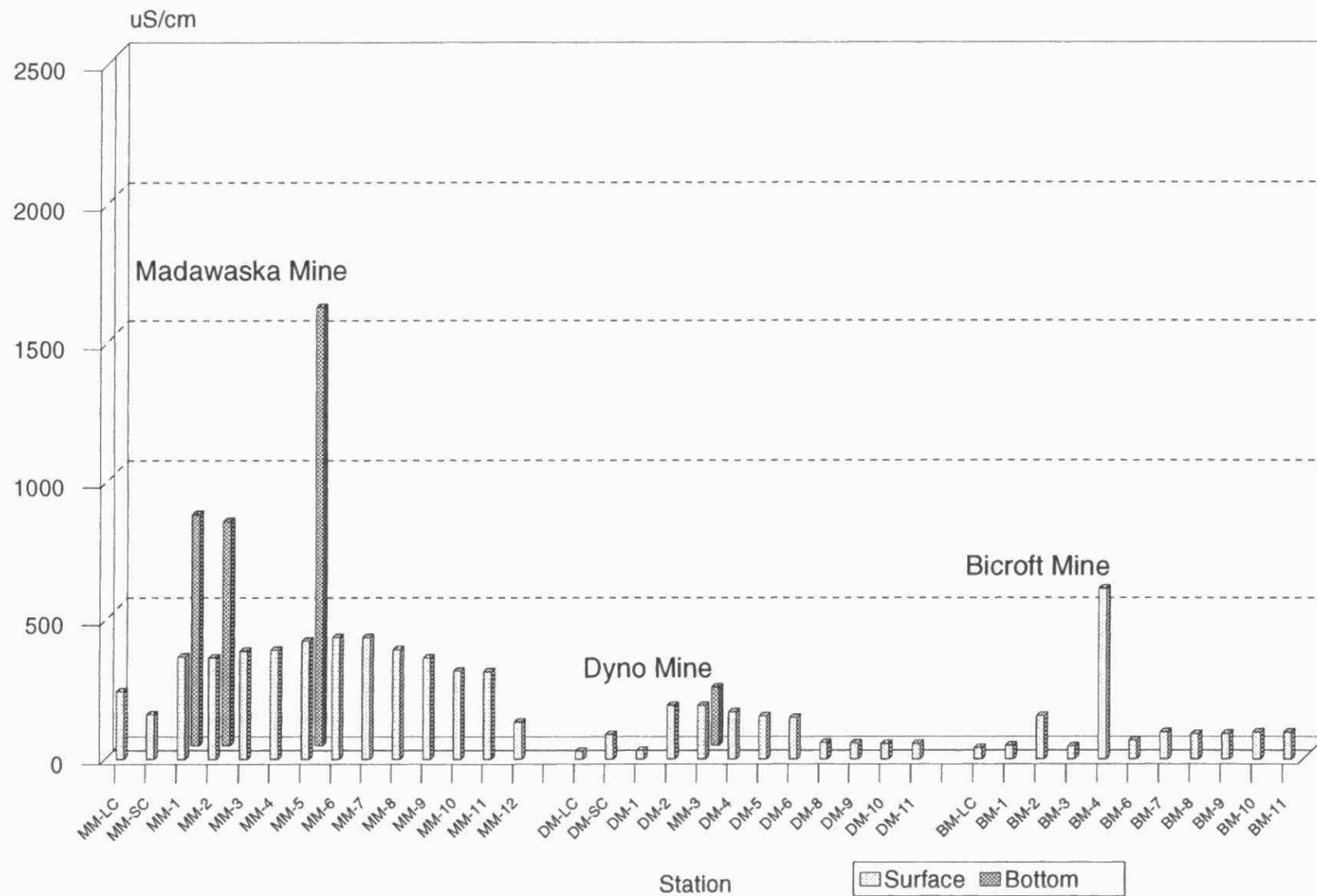
Figure 9b: Conductivity in Water, August 2000
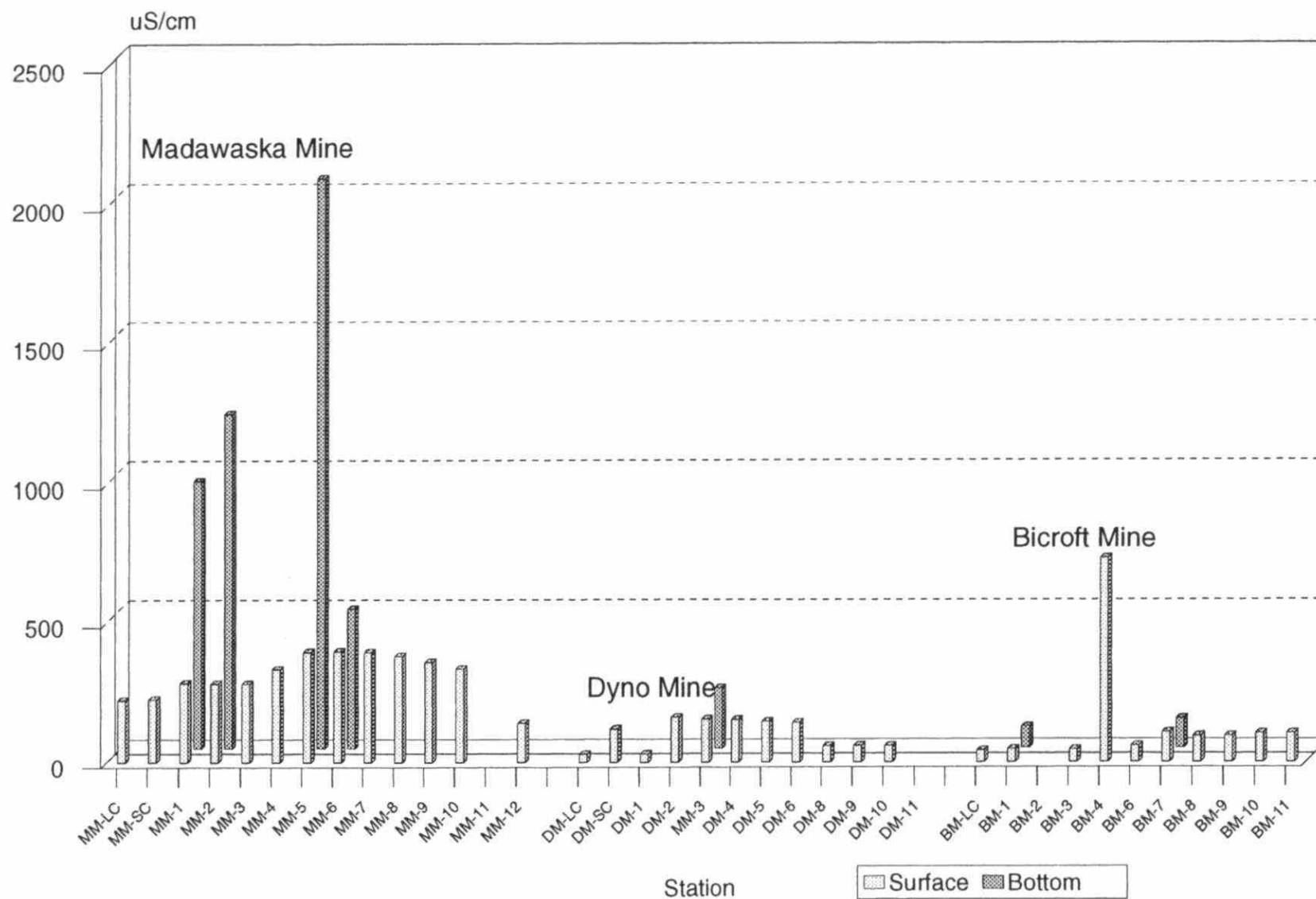
Figure 9c: Conductivity in Water, November 2000
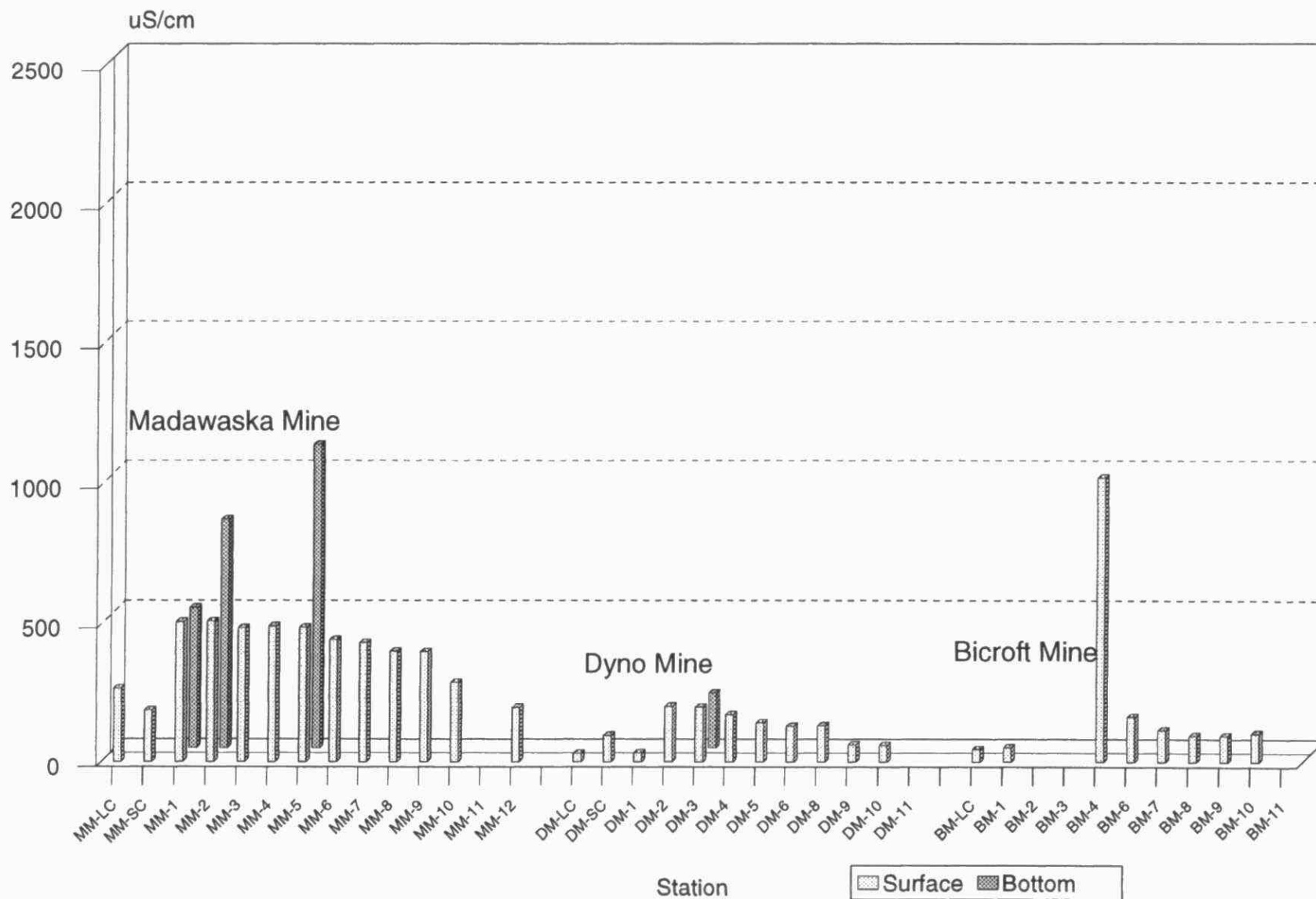
Figure 10a: Bentley Lake, Bow Lake and Siddon Lake Conductivity Profiles. May 2000
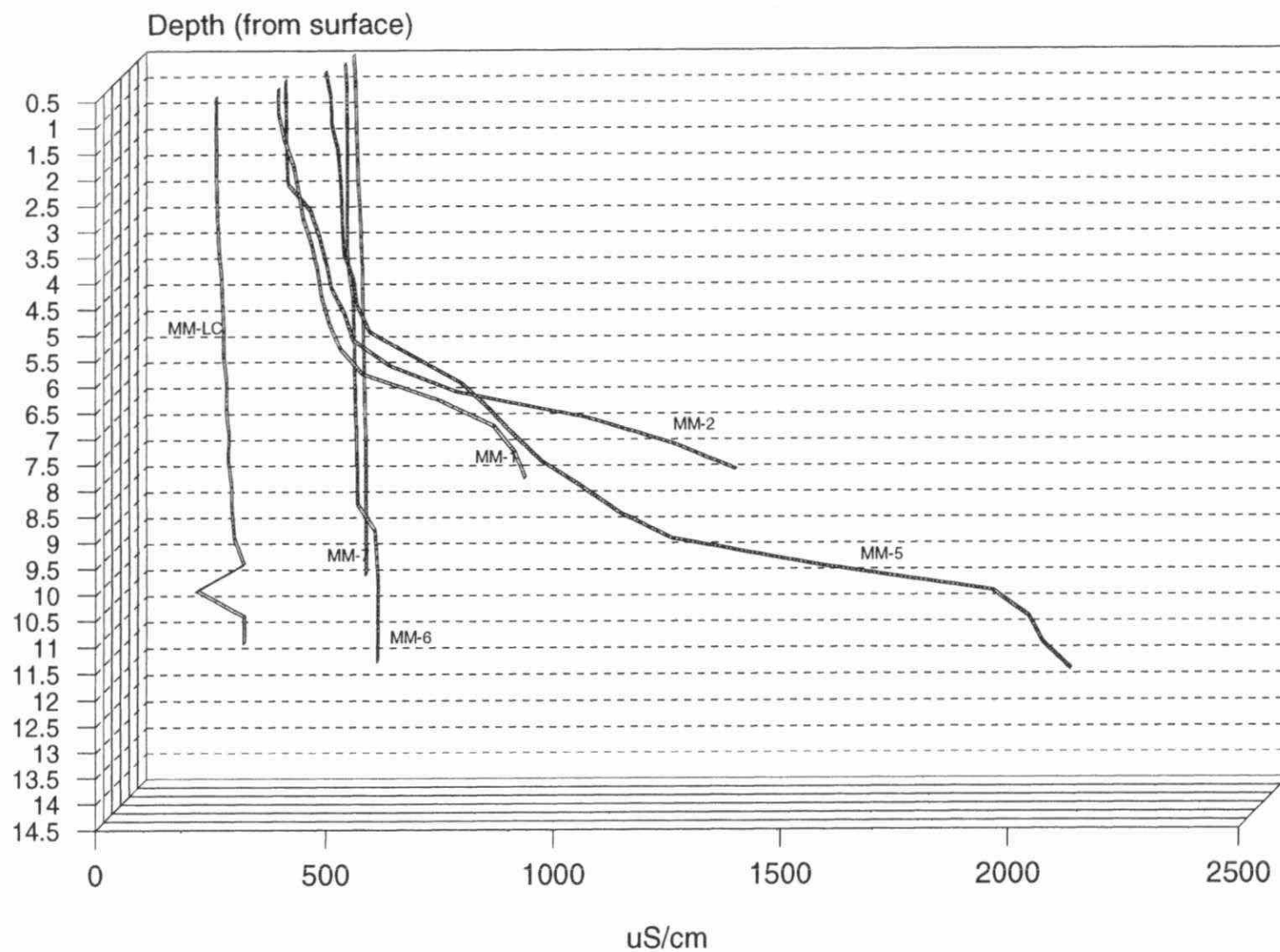
Figure 10b: Bentley Lake (MM-1) - Conductivity Profiles. May, August and Nov. 2000
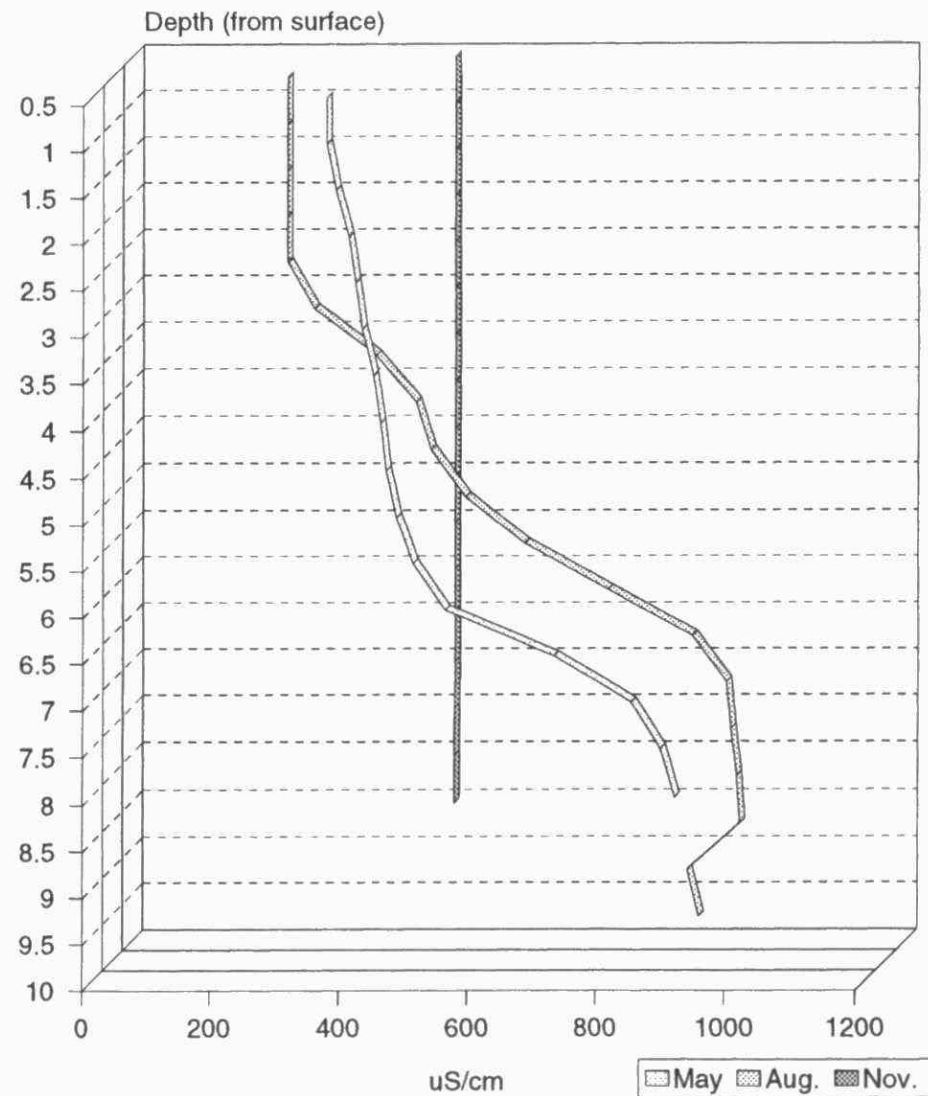
Figure 10c: Bentley Lake (MM-2) - Conductivity Profiles. May, August and Nov. 2000
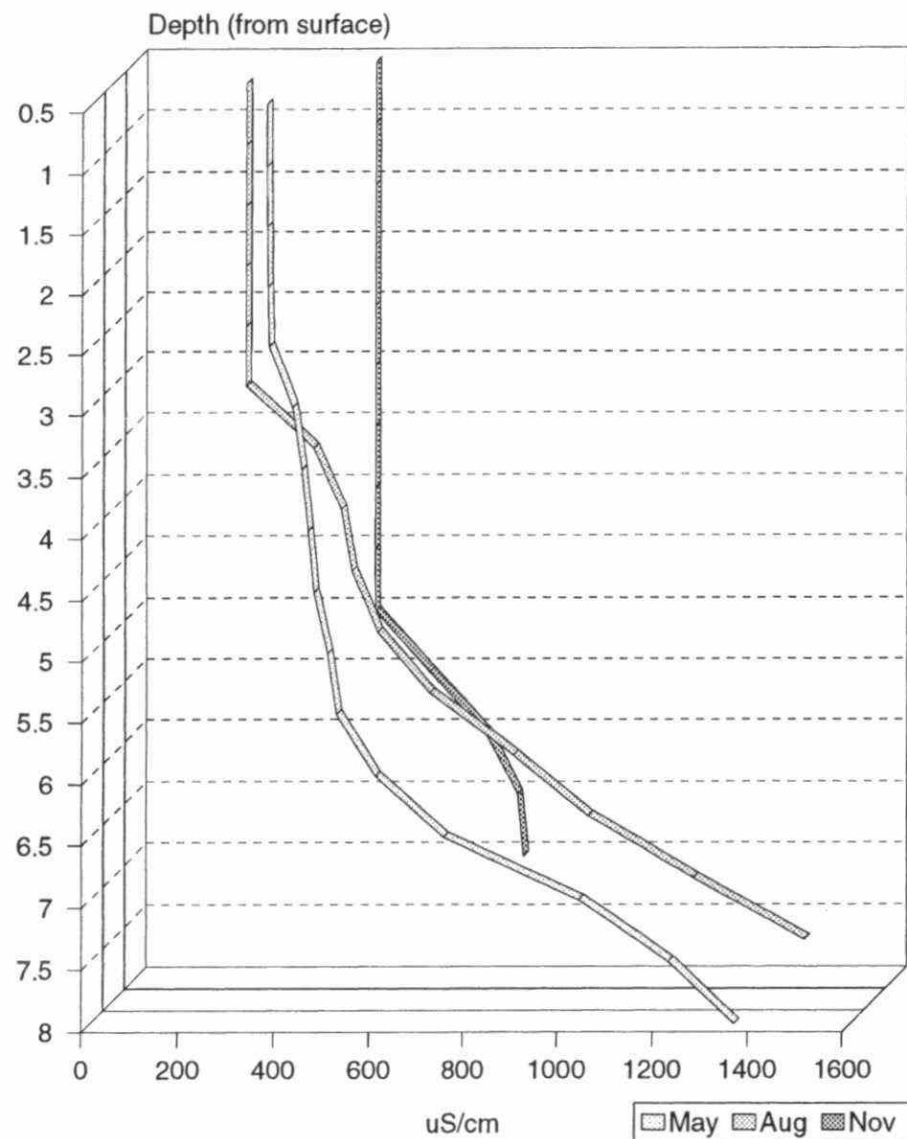
Figure 10d: Bow Lake (MM-5) - Conductivity Profiles. May, August and Nov. 2000
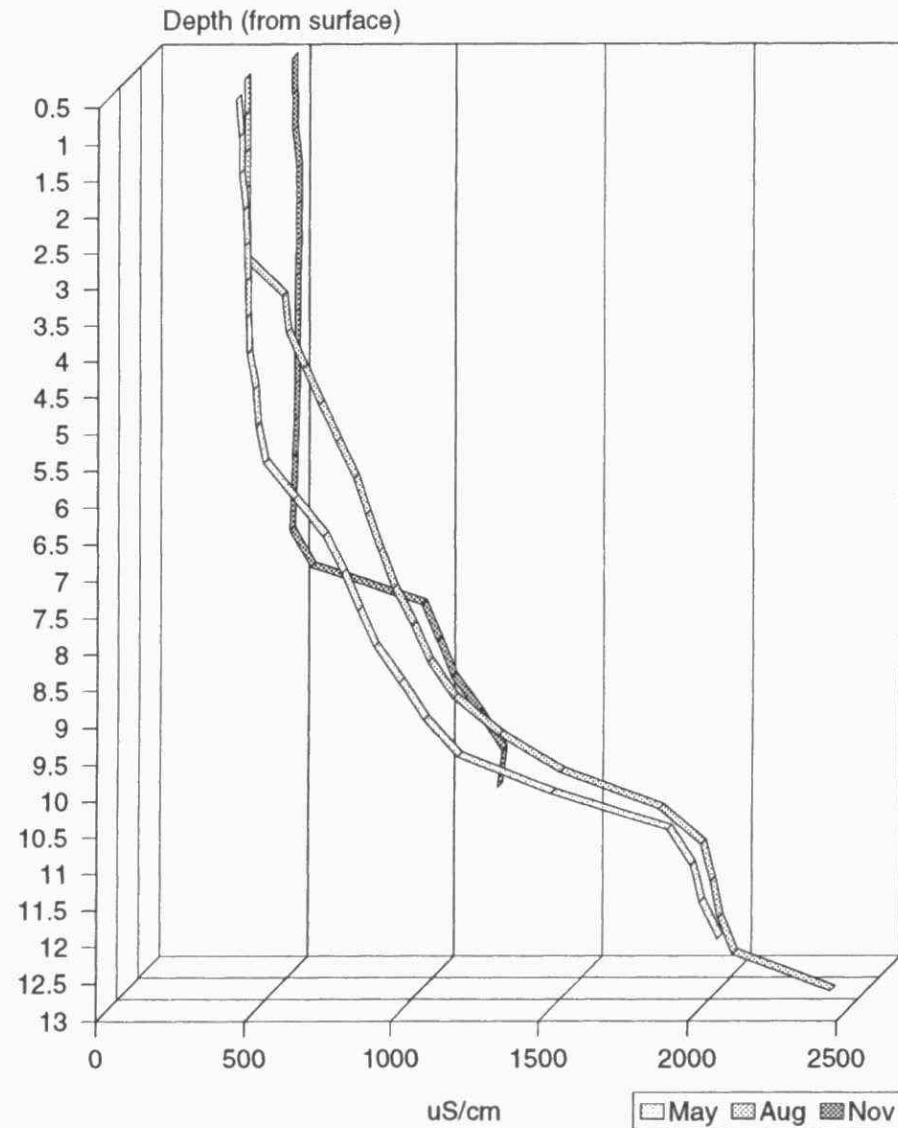
Figure 10e: Bow Lake (MM-6) - Conductivity
Profiles. May and August 2000
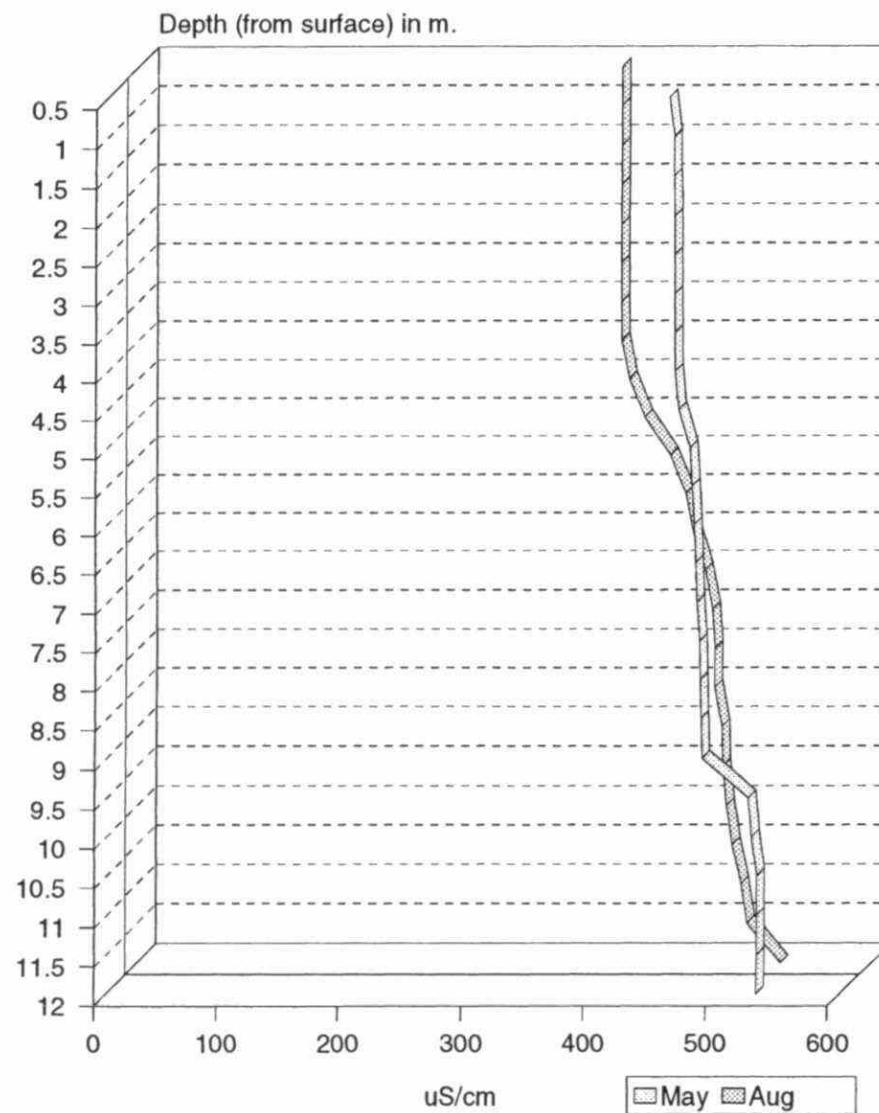
Figure 11a: Uranium Concentrations in Water, May 2000
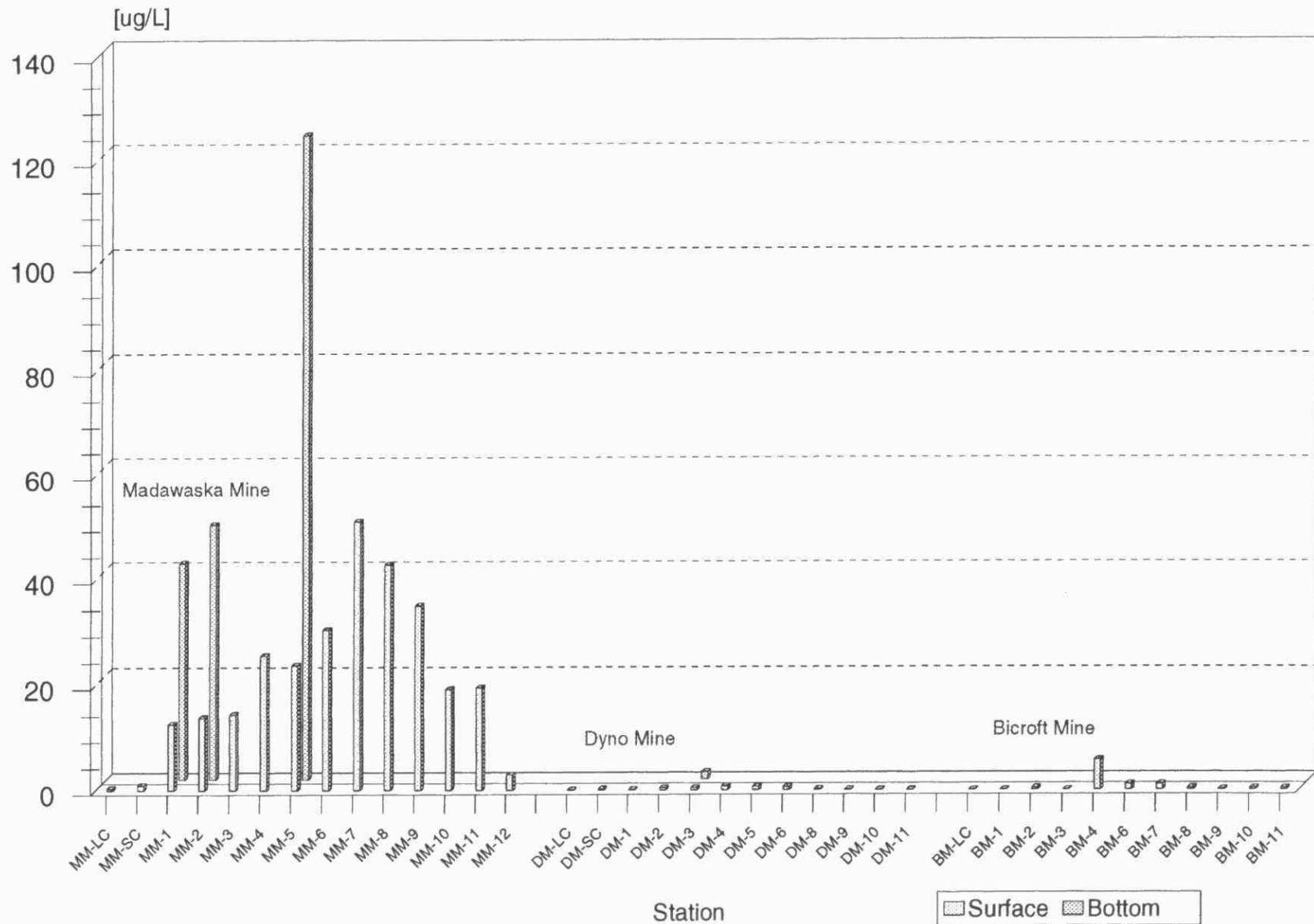
Figure 11b: Uranium Concentrations in Water, August 2000

Figure 11c: Uranium Concentrations in Water, November 2000
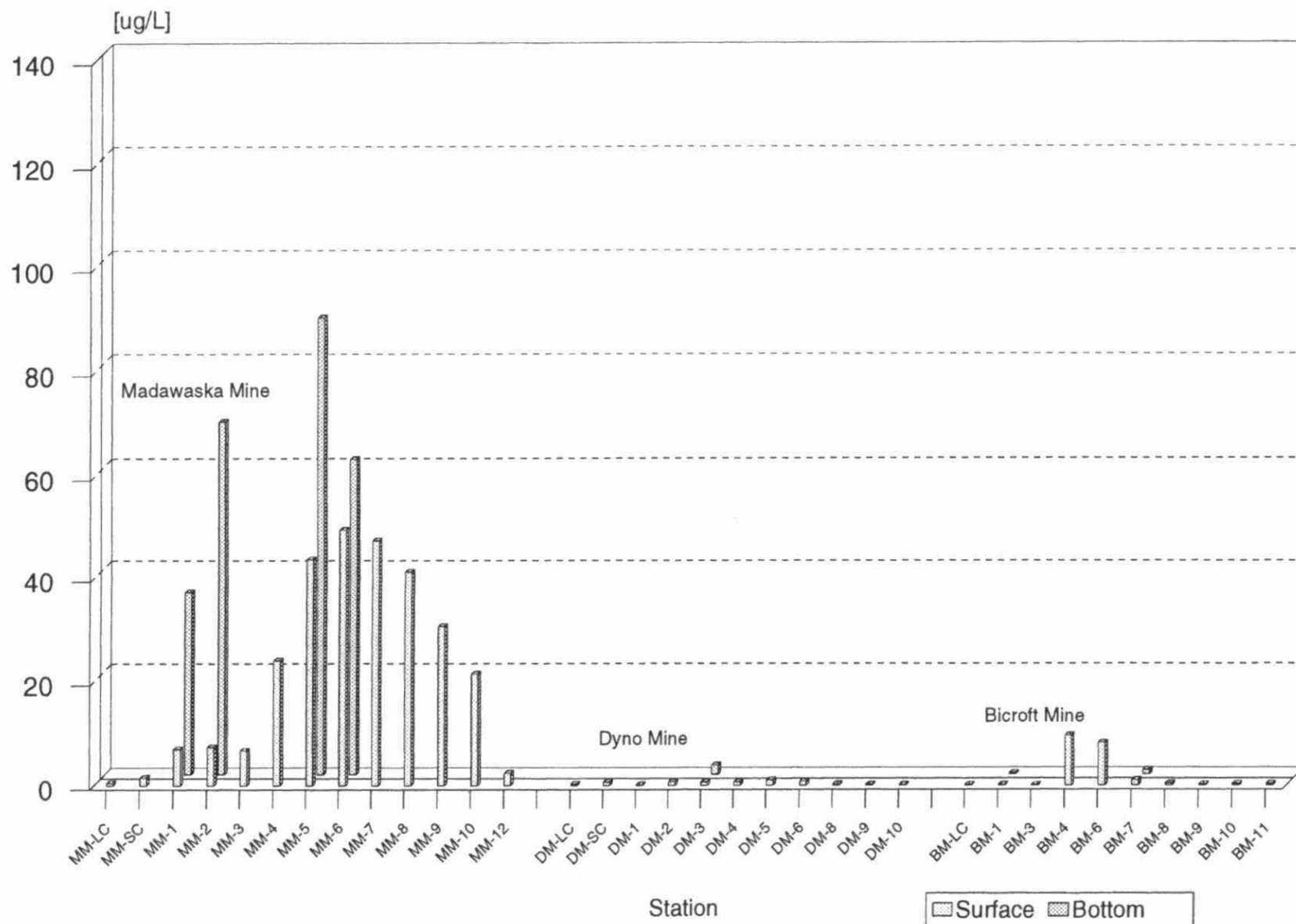
Figure 11c: Uranium Concentrations in Water, November 2000
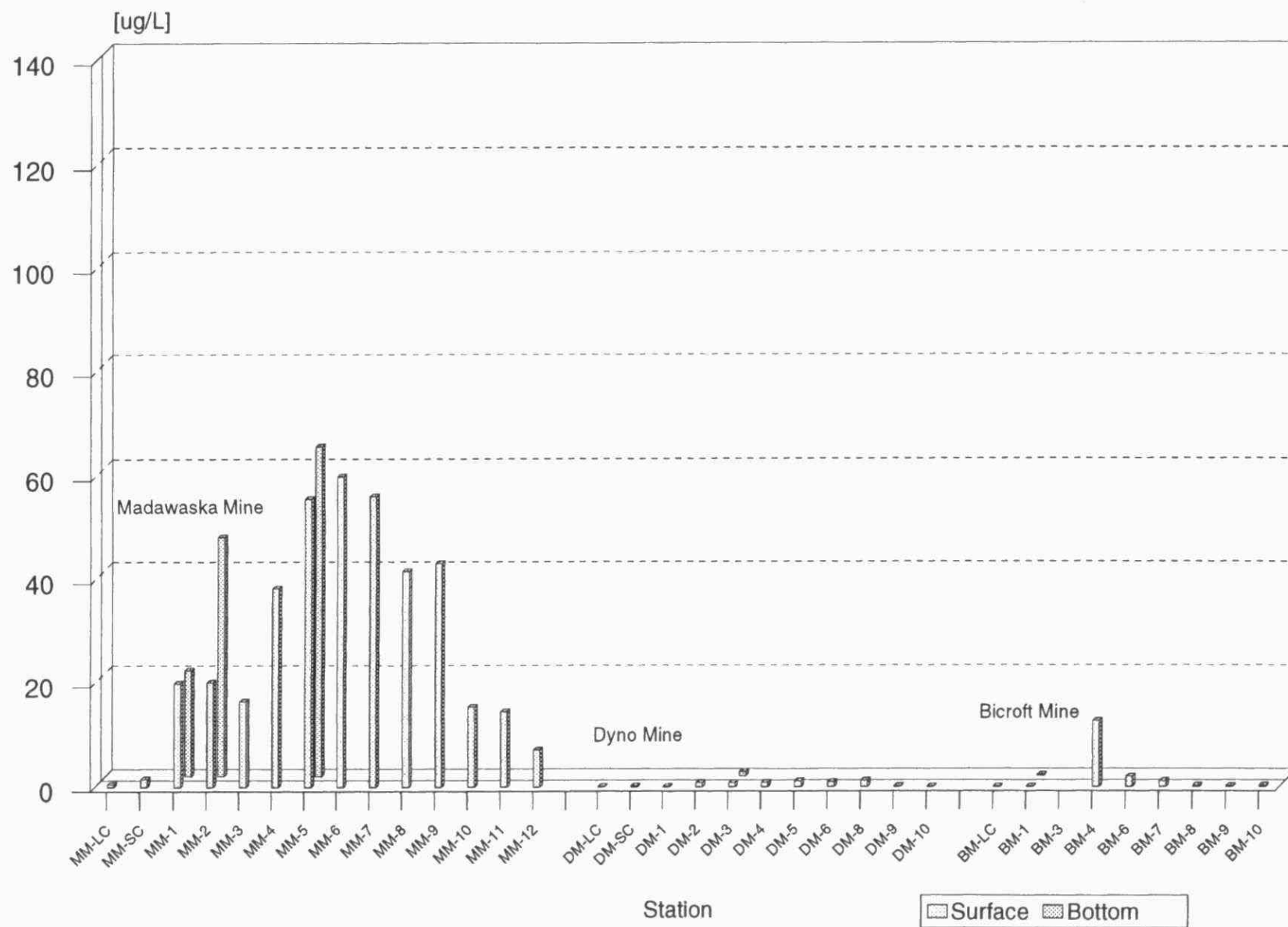
Figure 12a: Manganese Concentrations in Water, May 2000
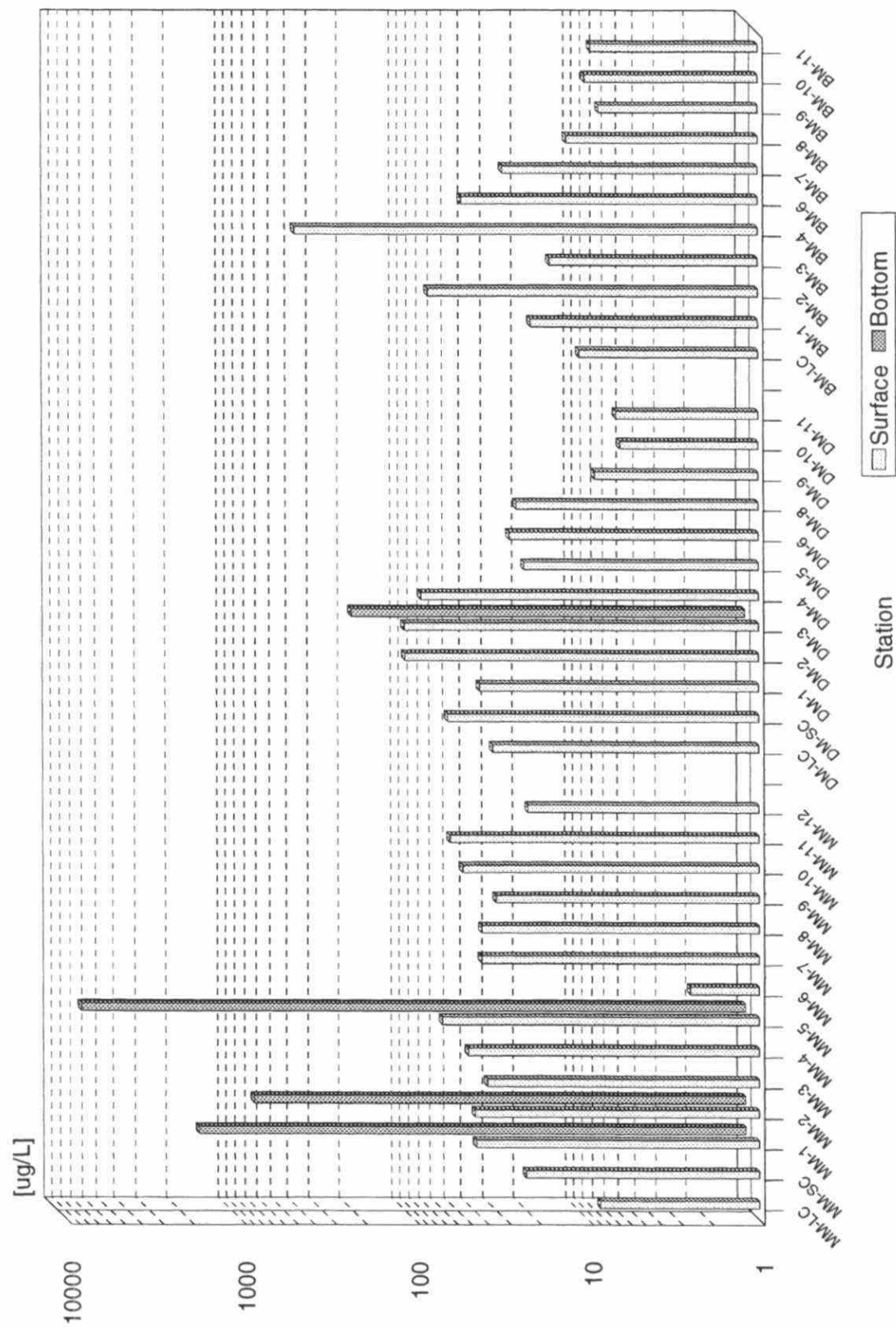
Figure 12b: Manganese Concentrations in Water, Aug. 2000
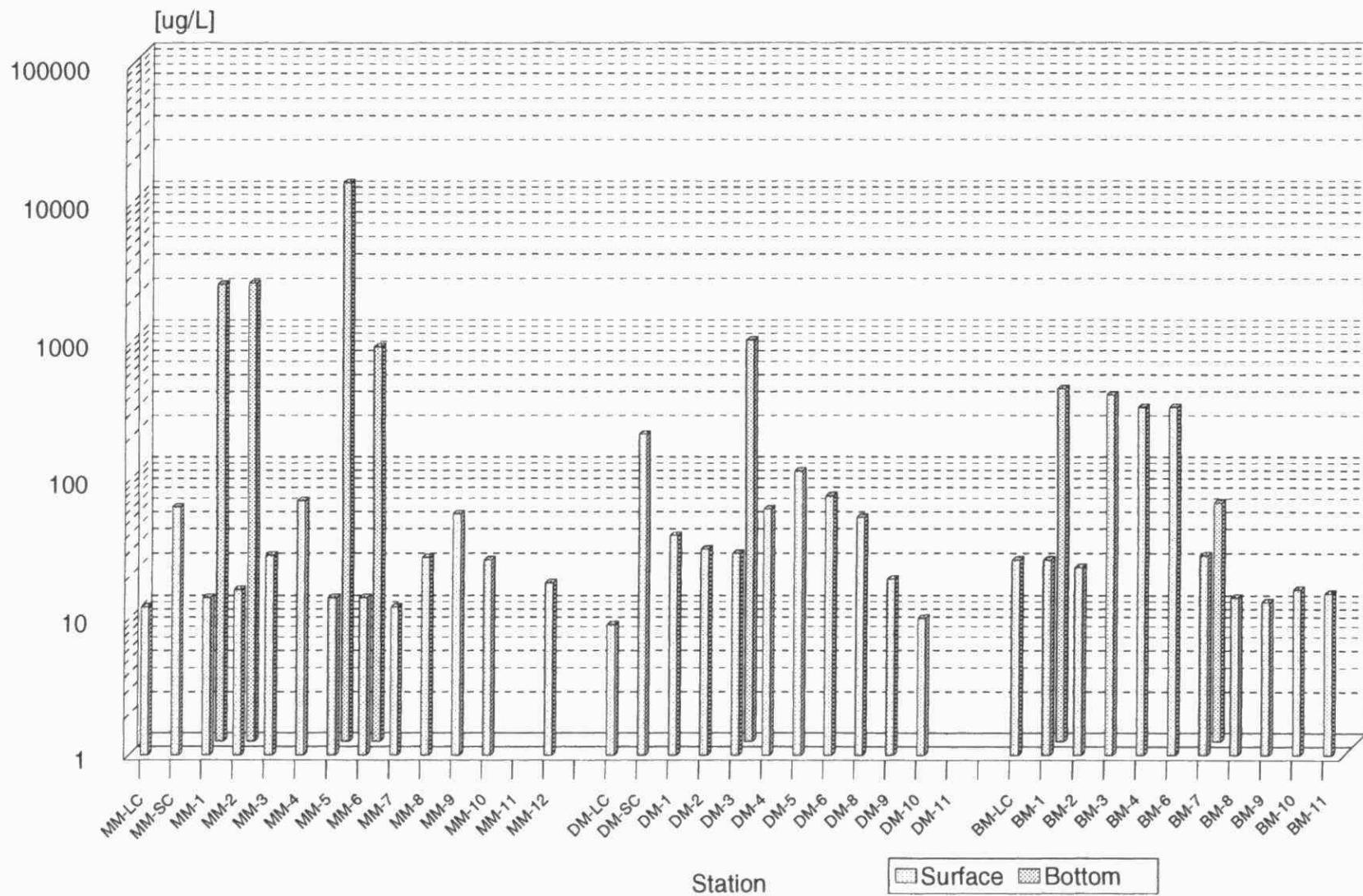
Figure 12c: Manganese Concentrations in Water, Nov. 2000

[ug/L]

Station

Surface Bottom
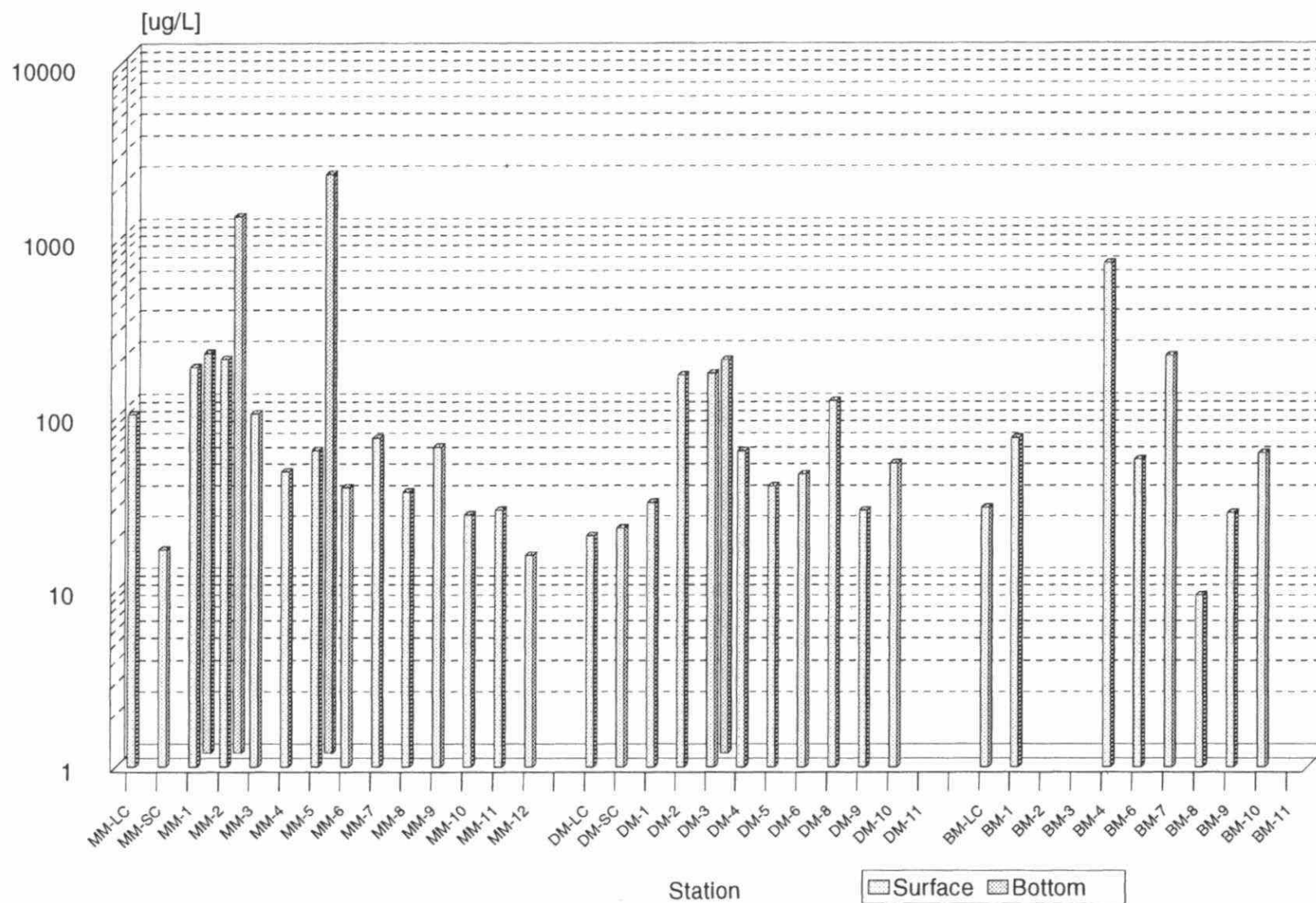
Figure 13a:Ra-226 Concentrations in Water, May 2000
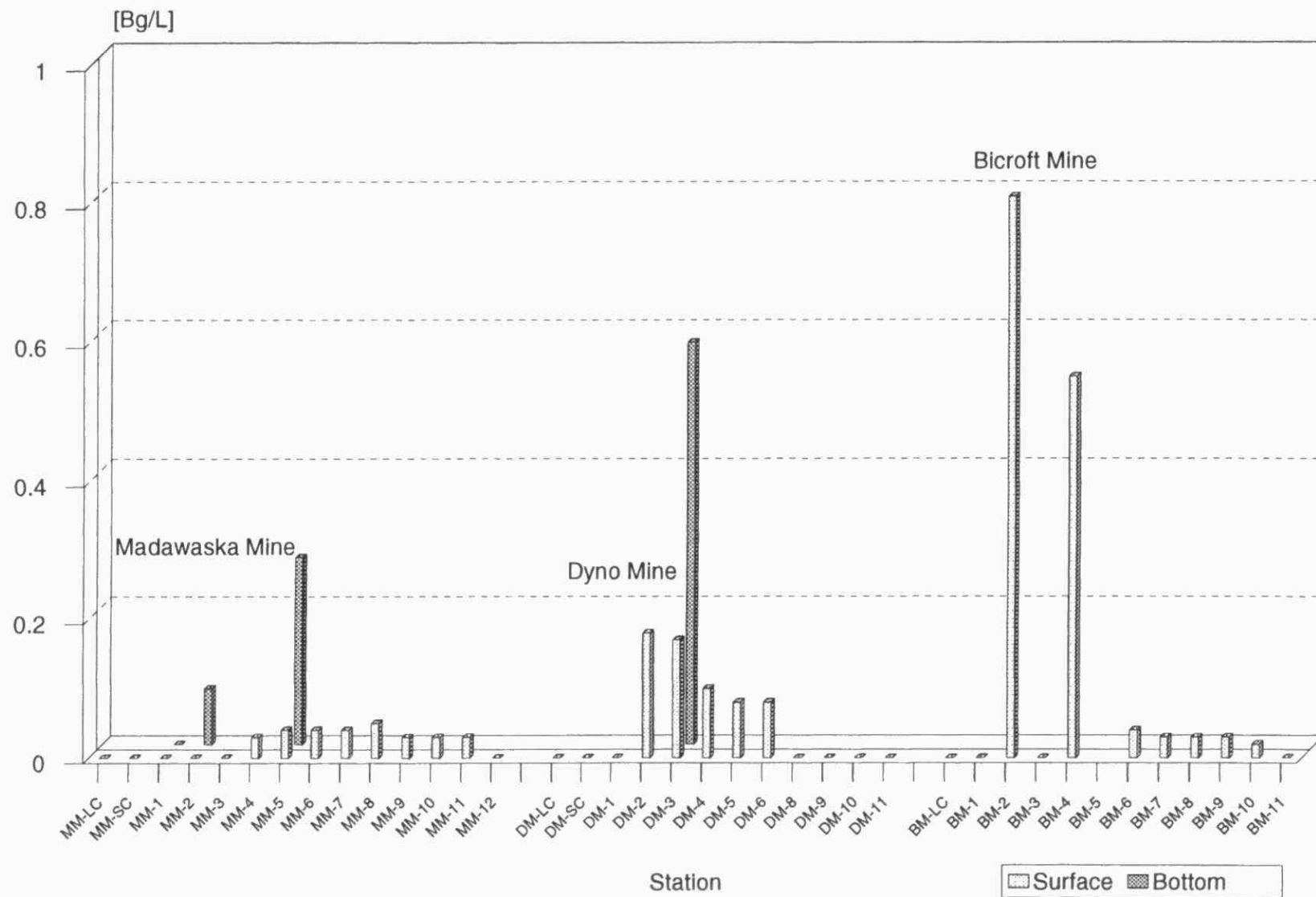
Figure 13b: Ra-226 Concentrations in Water, August 2000
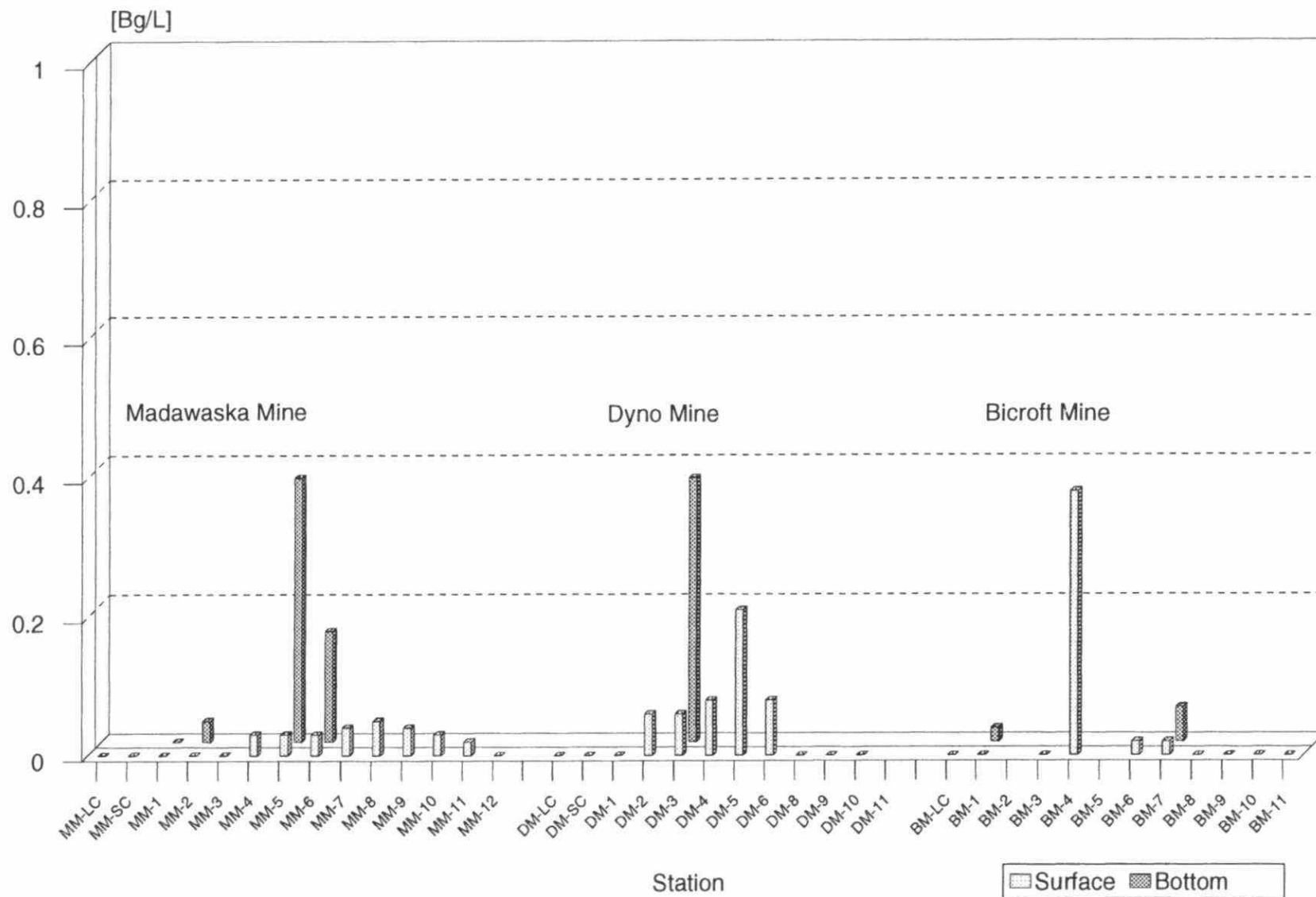
Figure 13c: Ra-226 Concentrations in Water, November 2000
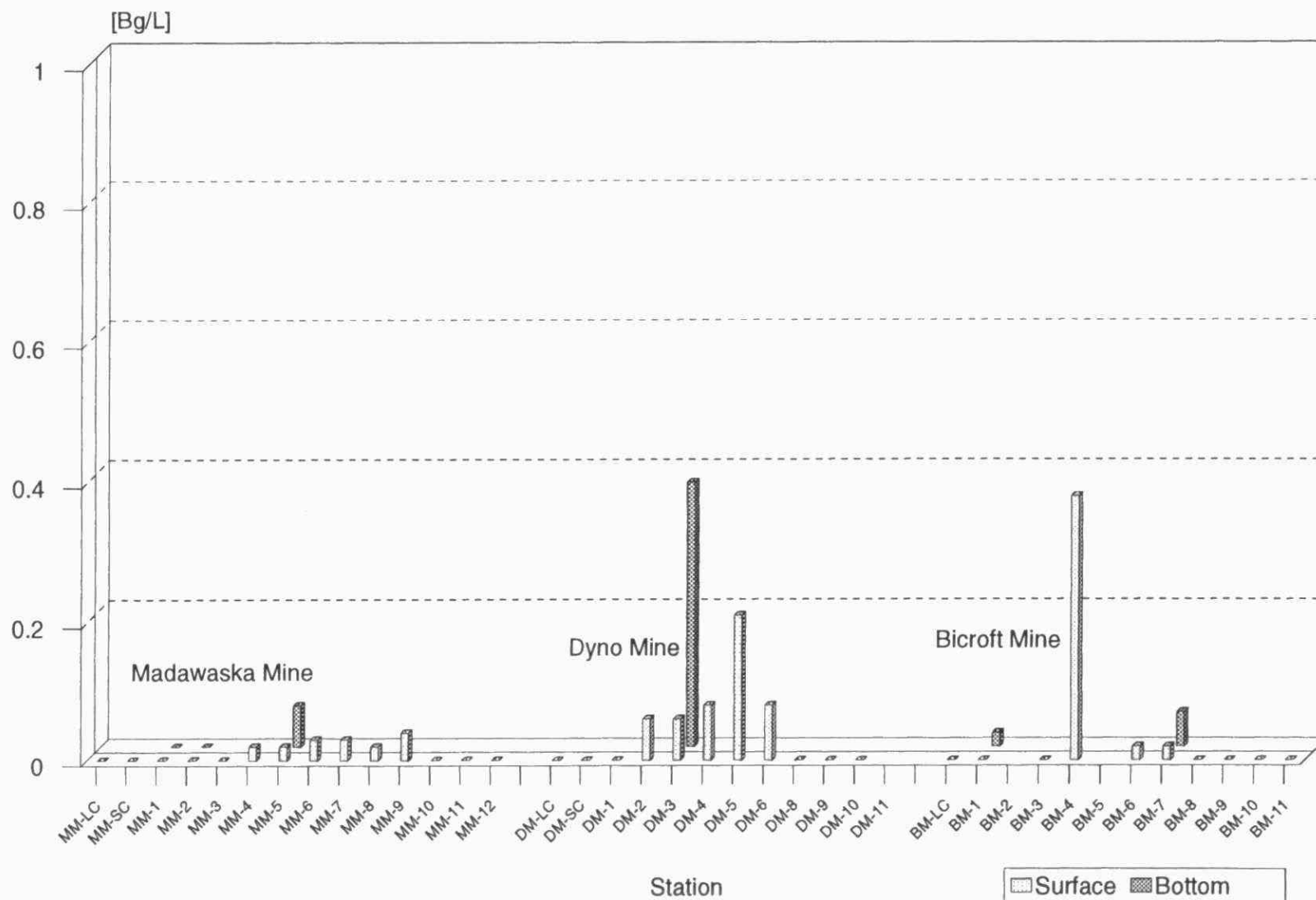
Figure 14a: Strontium Concentrations in Water, May 2000
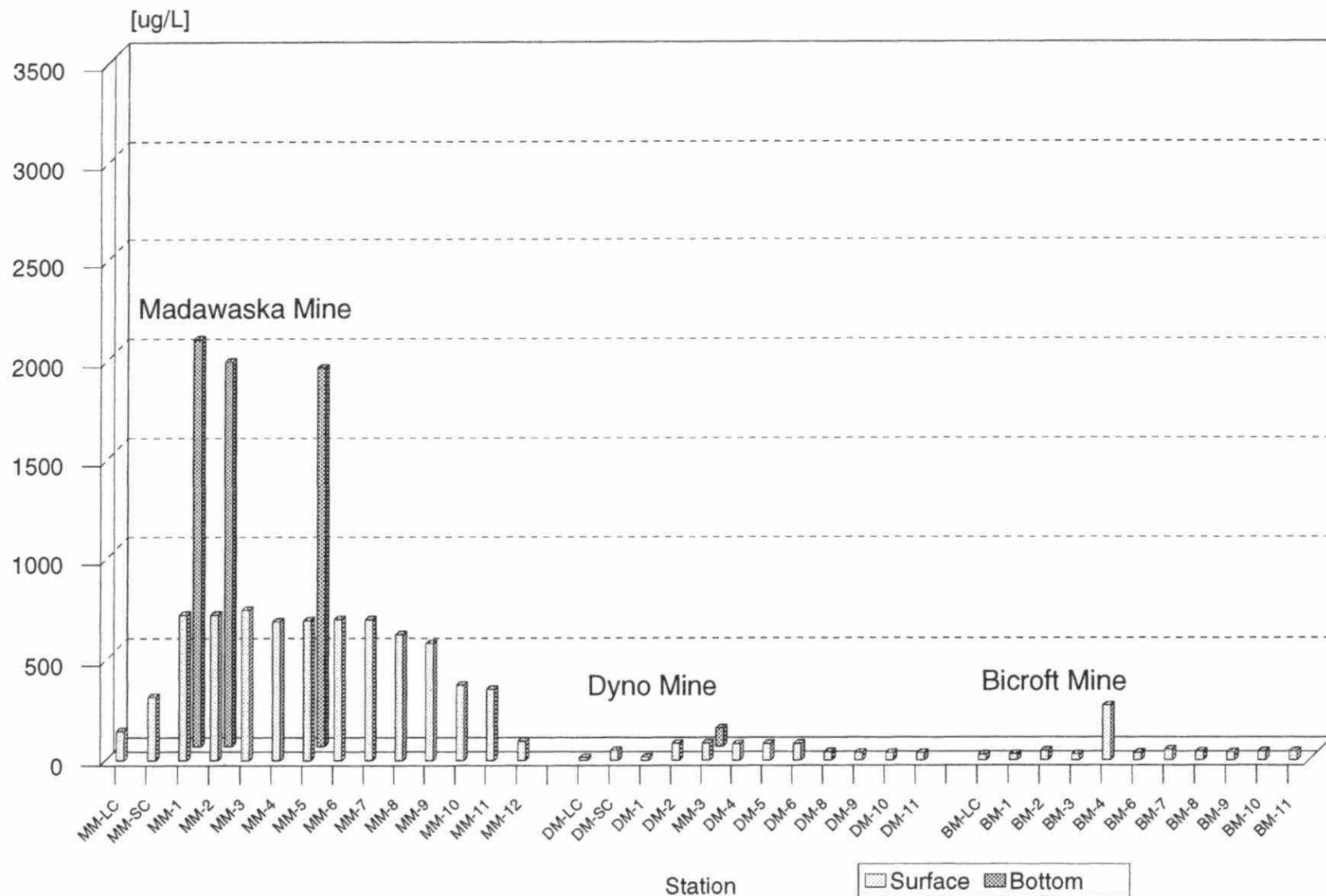
Figure 14b: Strontium Concentrations in Water, August 2000
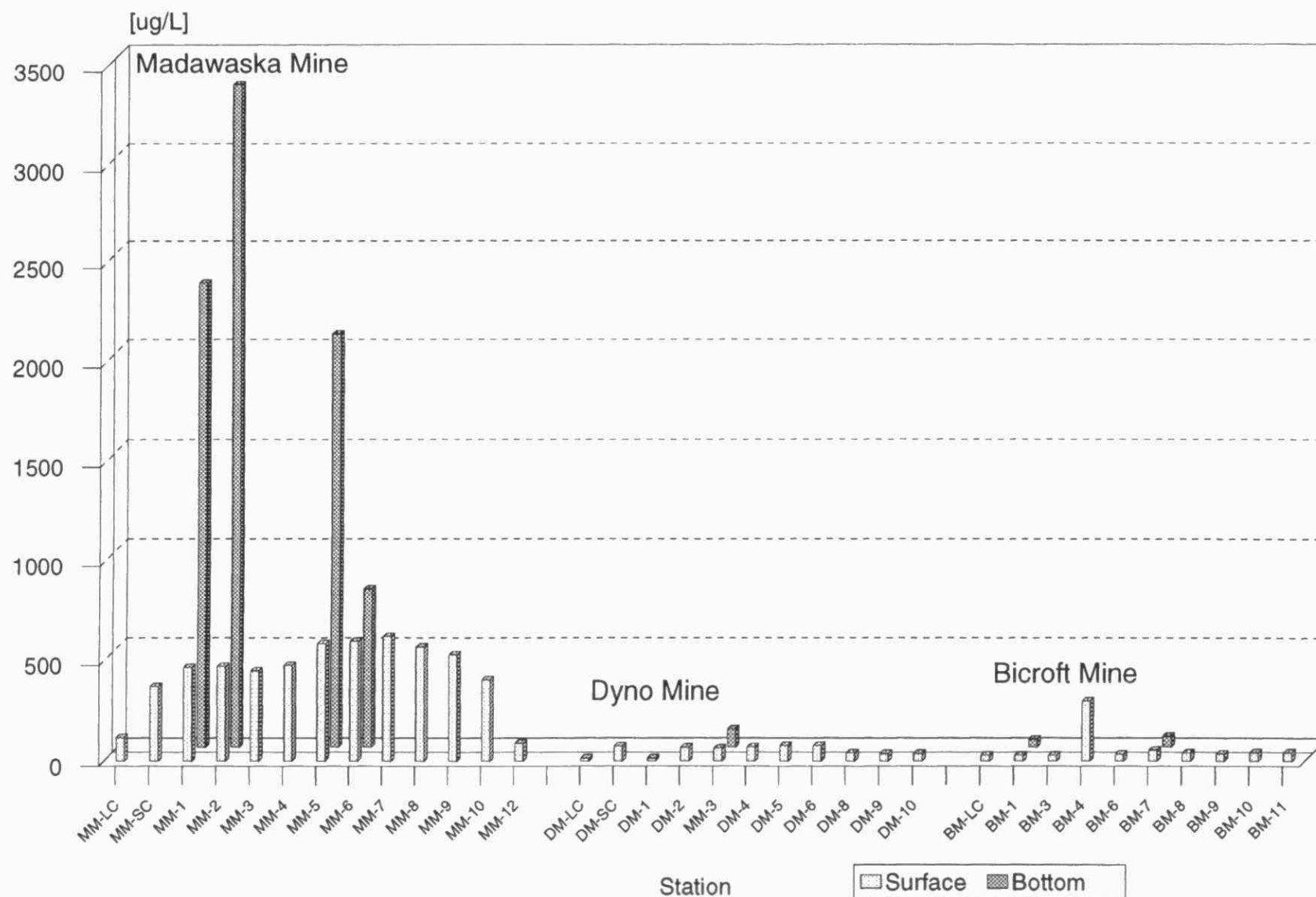
Figure 14c: Strontium Concentrations in Water, November 2000
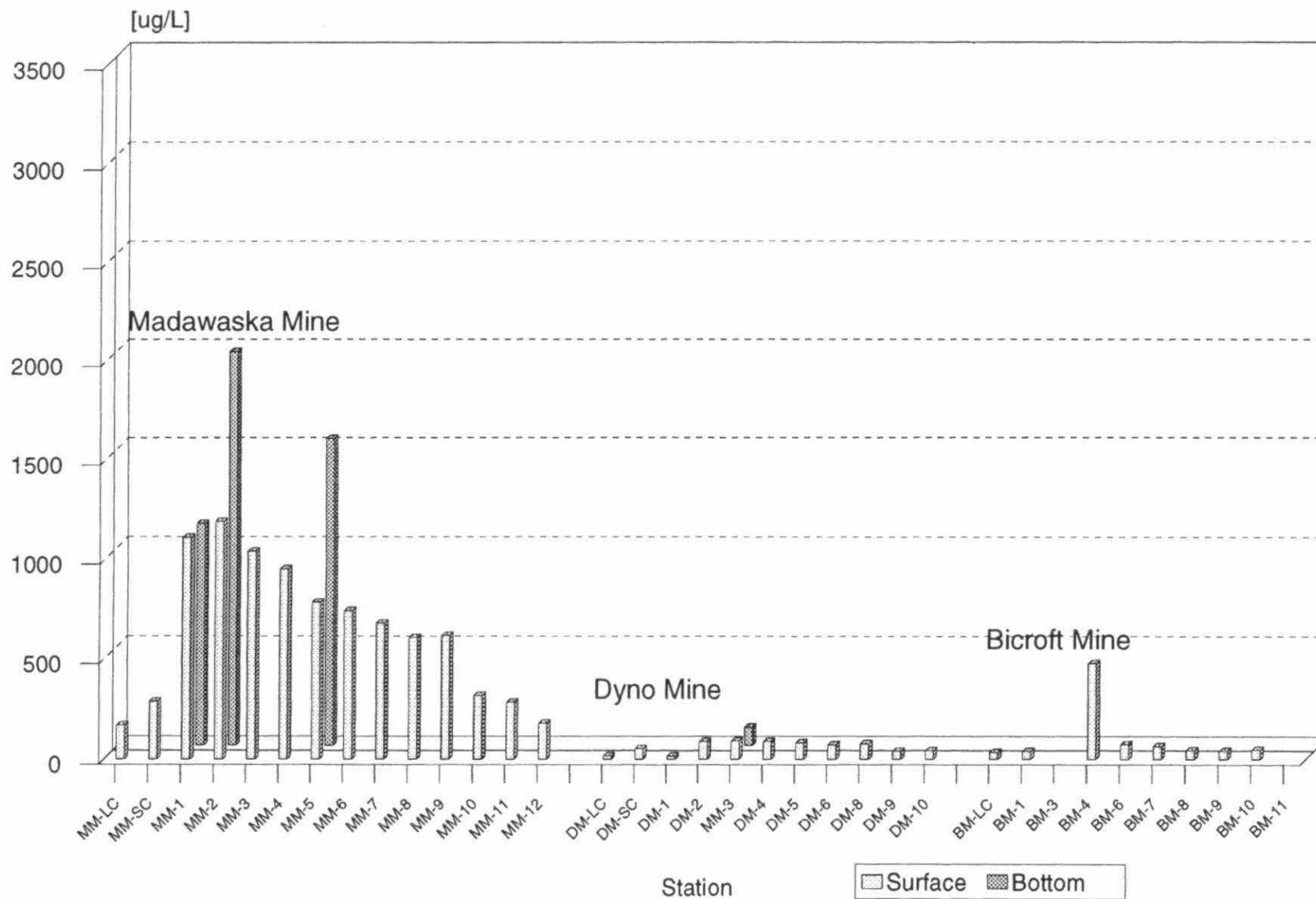
Figure 15a: Mean Yearly Concentrations of Ra-226 and Uranium in Bentley Ck. below Bentley Lake (Station MM-3)
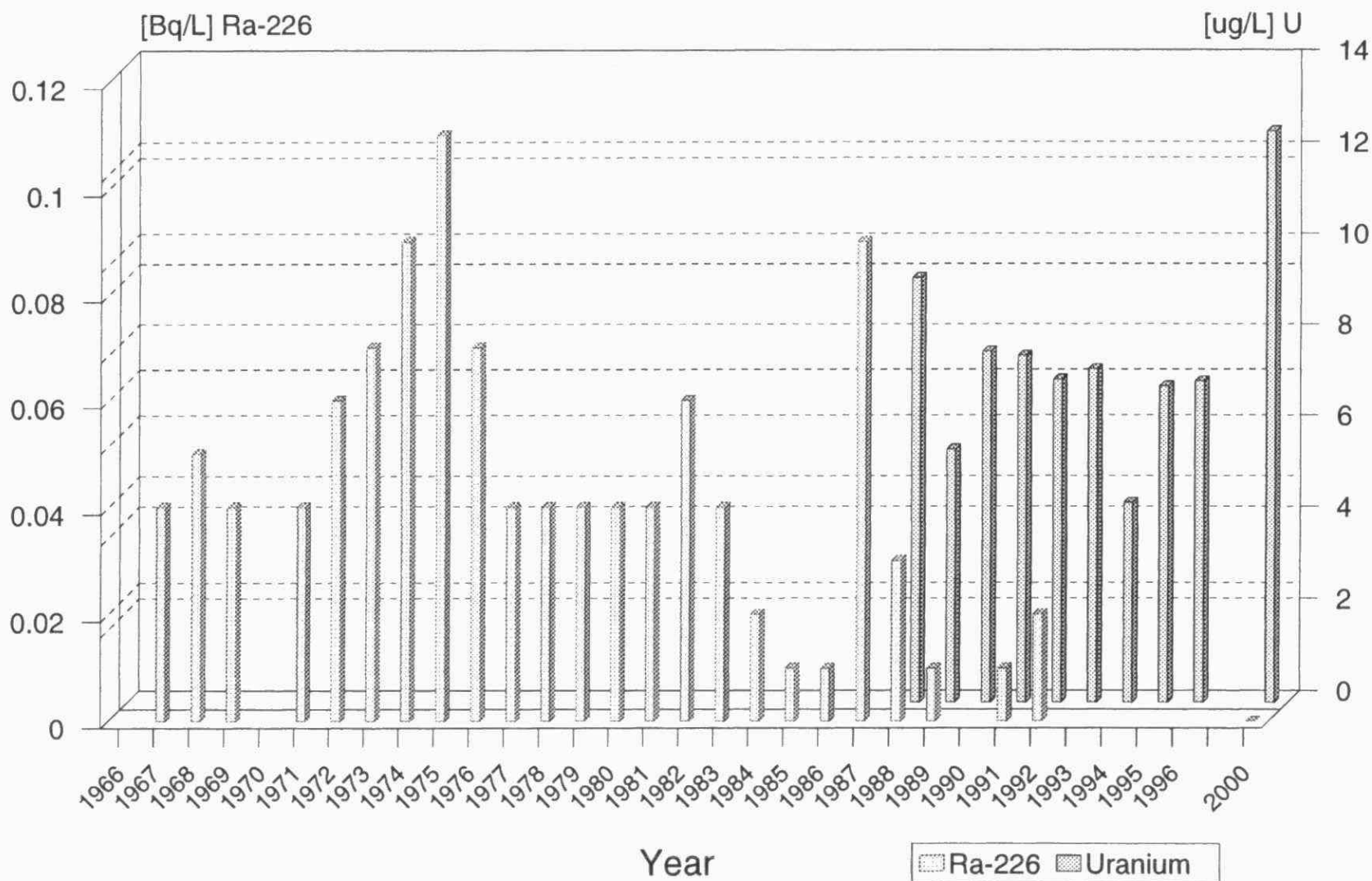
Figure 15b: Mean Yearly Concentrations of Ra-226 and Uranium in Bentley Ck. above Bow Lake (Station MM-4)
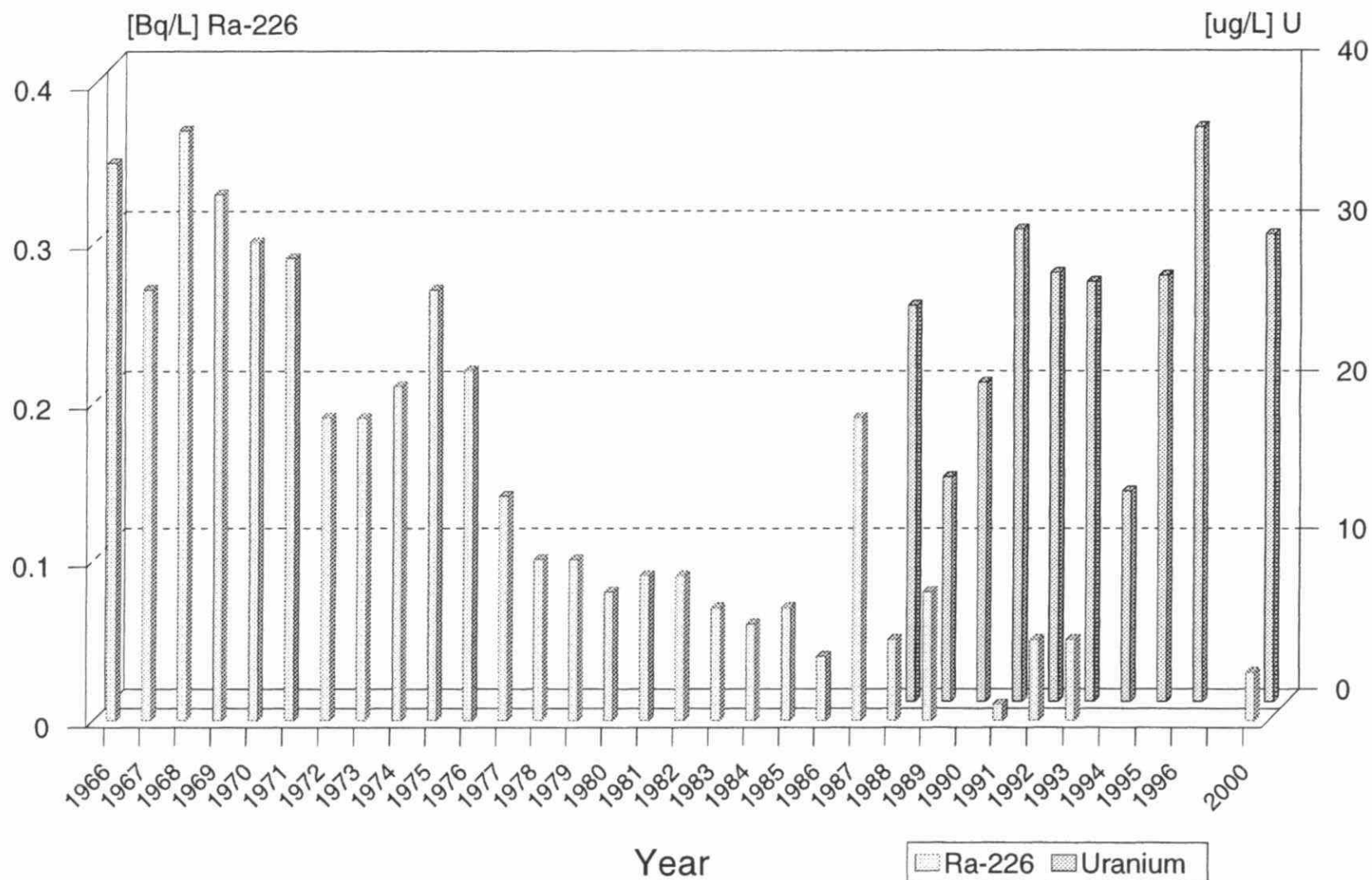
Figure 15c: Mean Yearly Concentrations of Ra-226 and Uranium at Bow Lake Outlet (between Station MM-7 and MM-8)
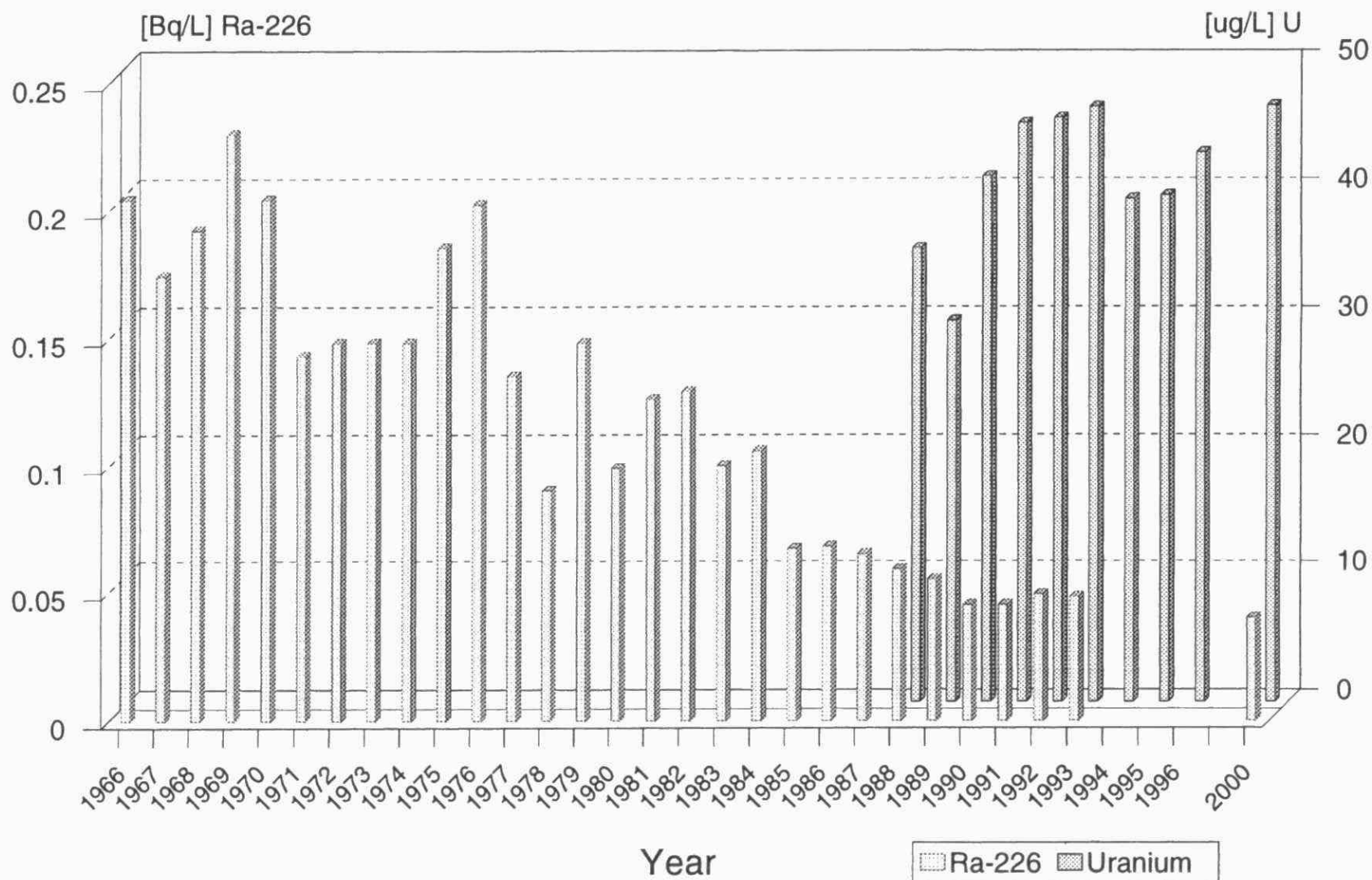
Figure 15d: Mean Yearly Concentrations of Ra-226 and Uranium in Farrel Ck. below Farrel Lake (Station DM-5)
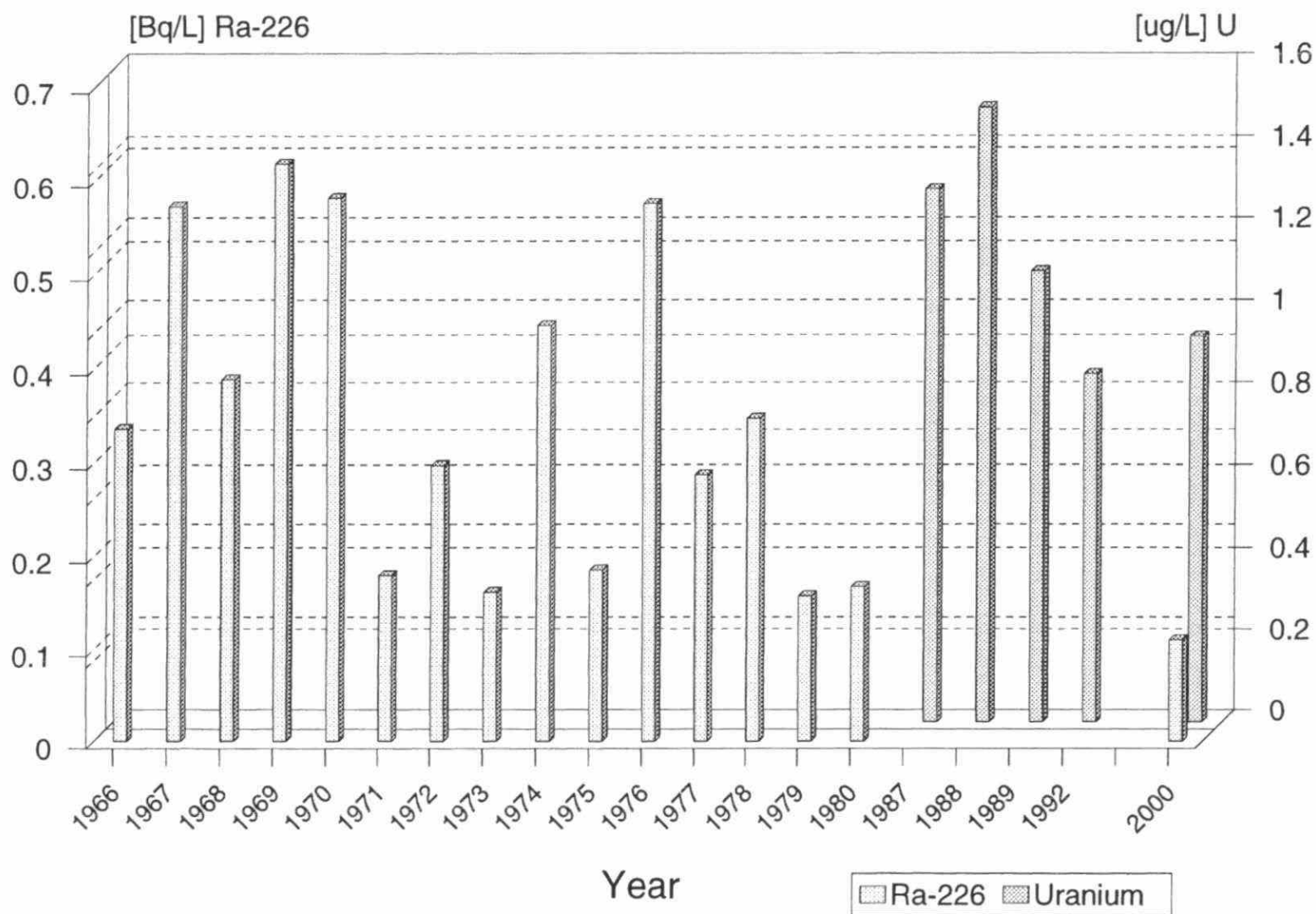
Figure 15e: Mean Yearly Concentrations of Ra-226 and Uranium in Deer Ck. (Paudash Lake) (Station BM-6)
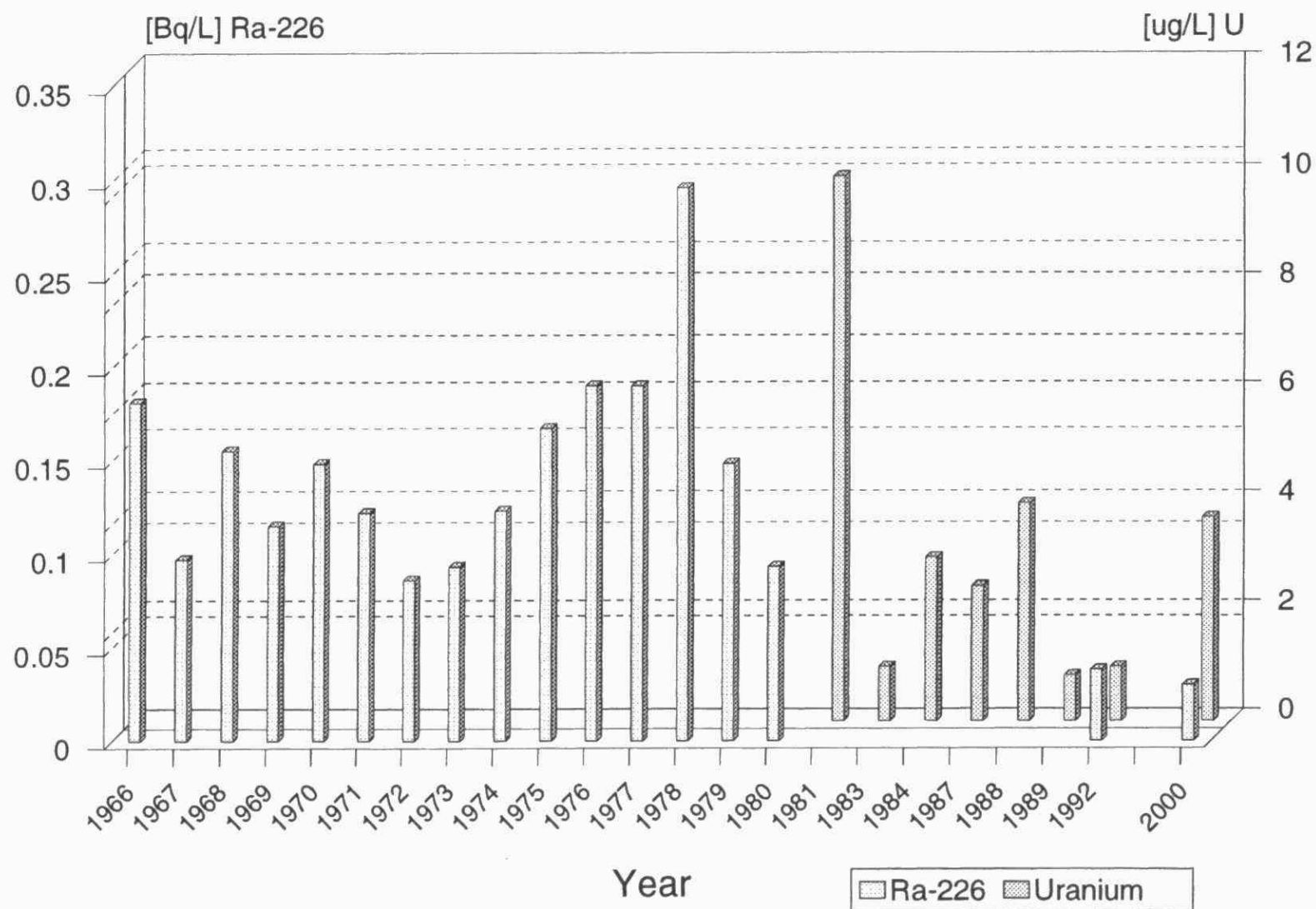
Figure 16a: Mean Monthly Distribution of Manganese at PWQMN Sites. 1970-1999 - Madawaska Mine
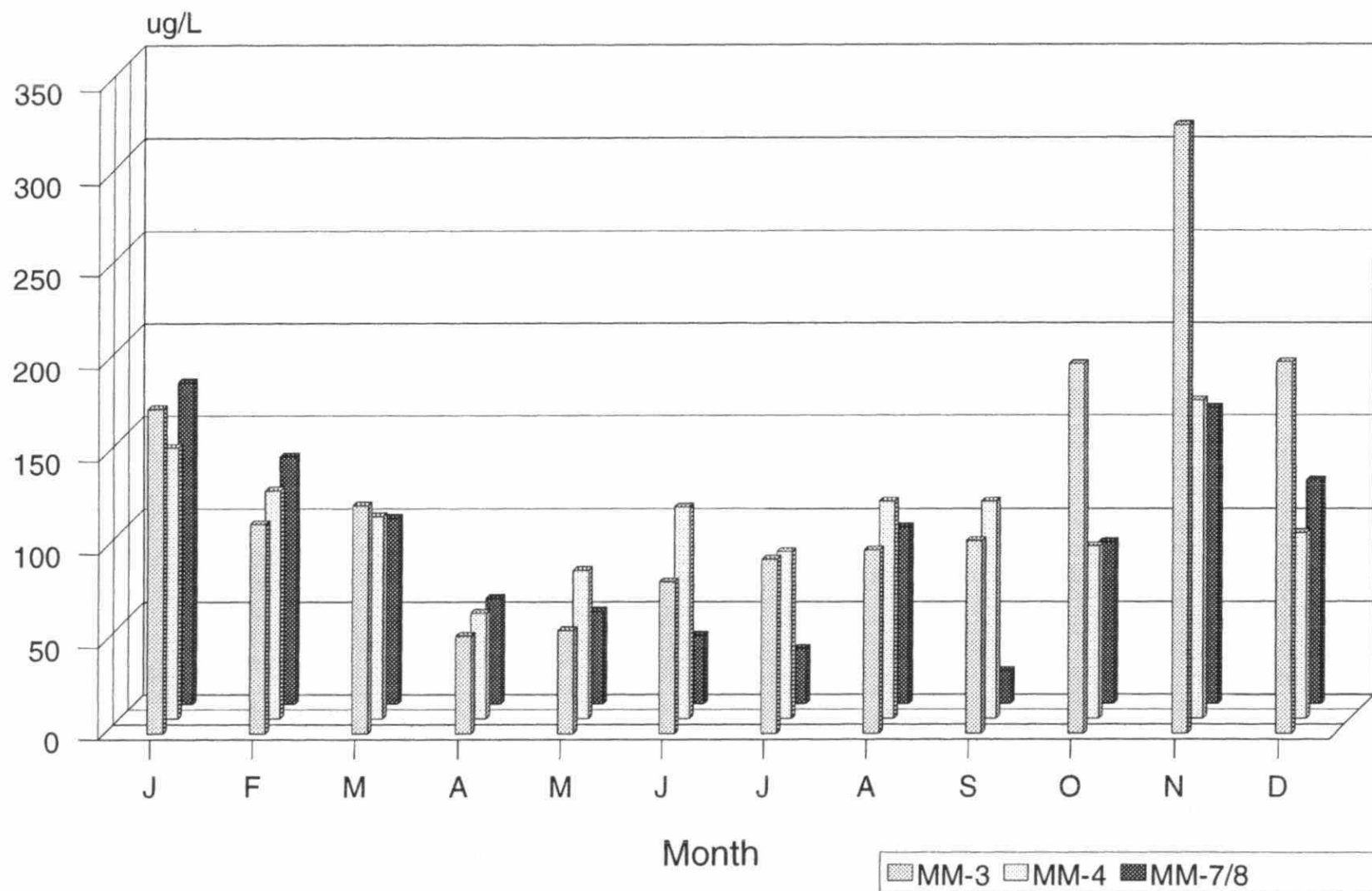
Figure 16b: Mean Monthly Distribution of Manganese at PWQMN Sites. 1970-1999 - Bicroft Mine
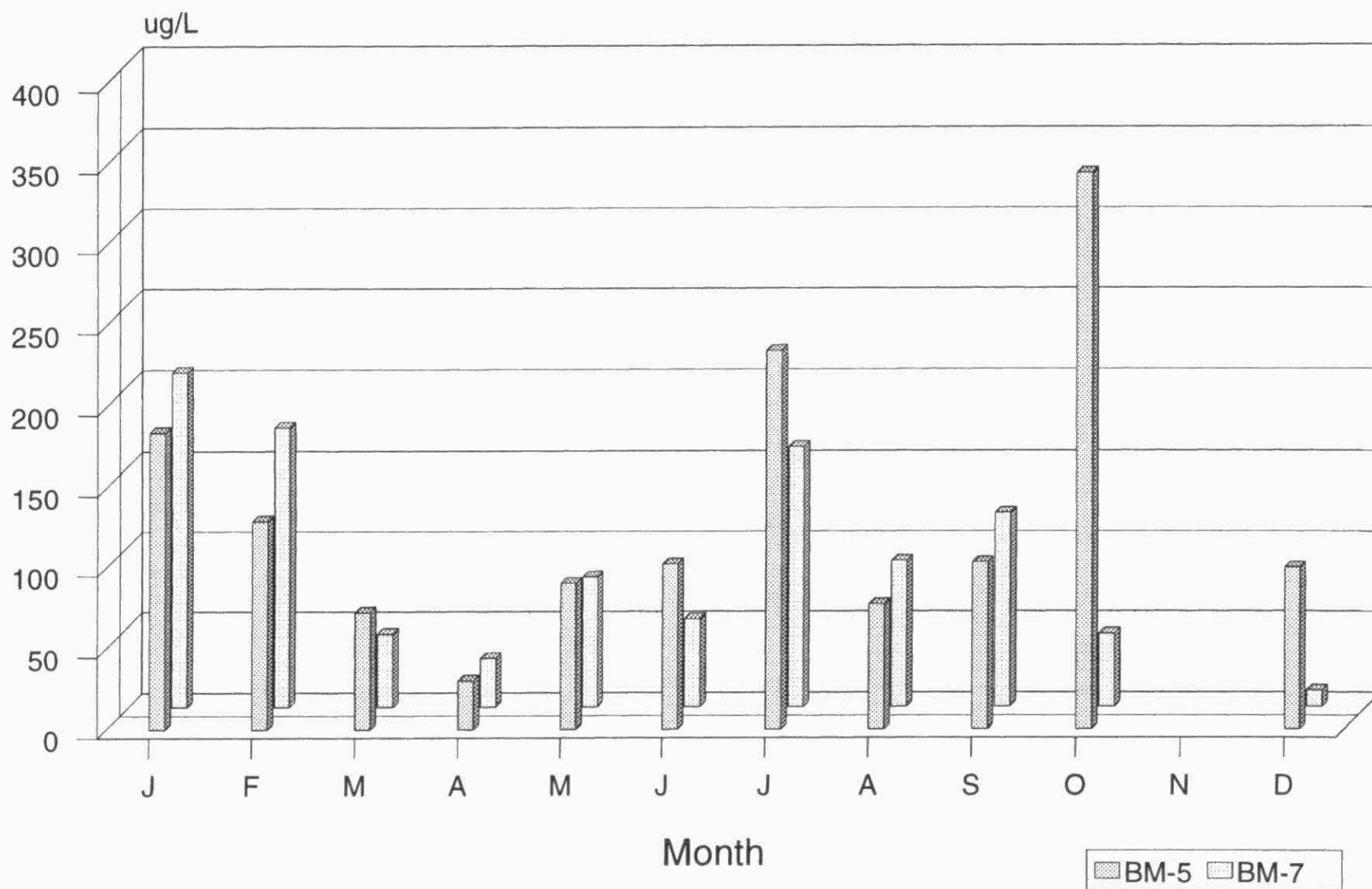
Figure 17a: Mean Monthly Distribution of Uranium at PWQMN Sites. 1990-1999 - Madawaska Mine
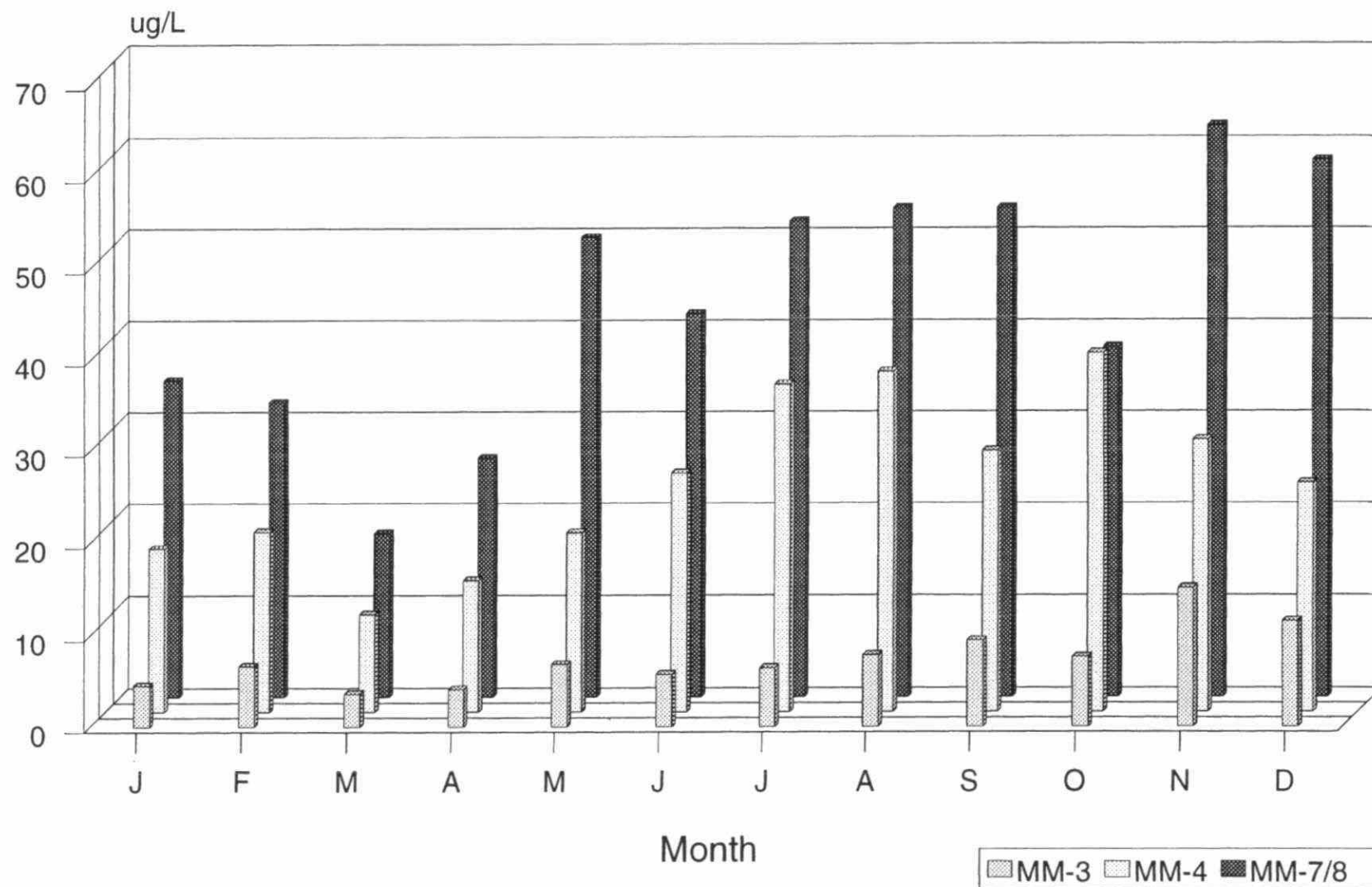
Figure 17b: Mean Monthly Distribution of Uranium at PWQMN Sites. 1970-1999 - Bicroft Mine
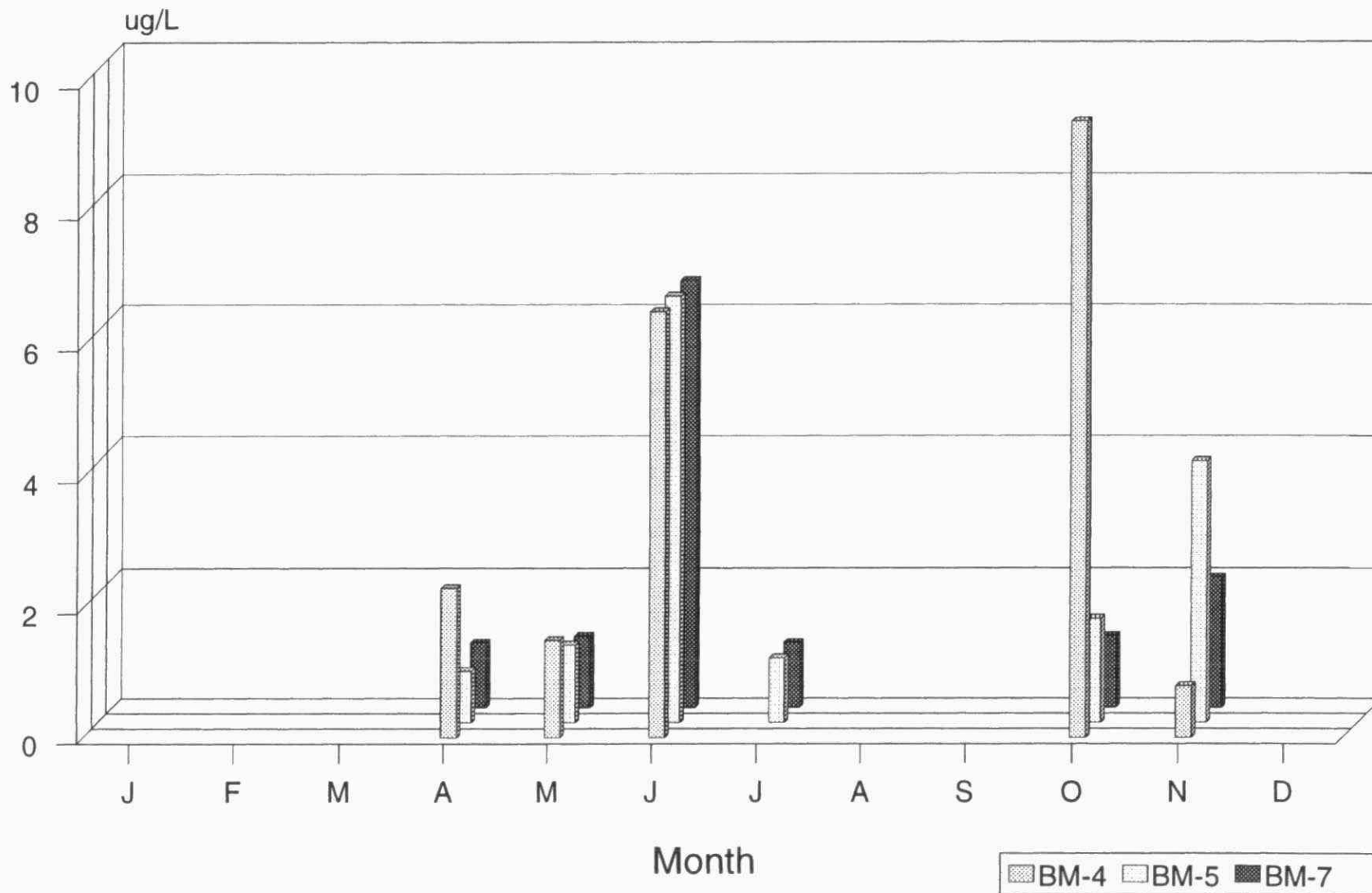
Figure 18: Mean Monthly Distribution of Radium-226 at PWQMN Sites. 1990-1999 - Madawaska Mine
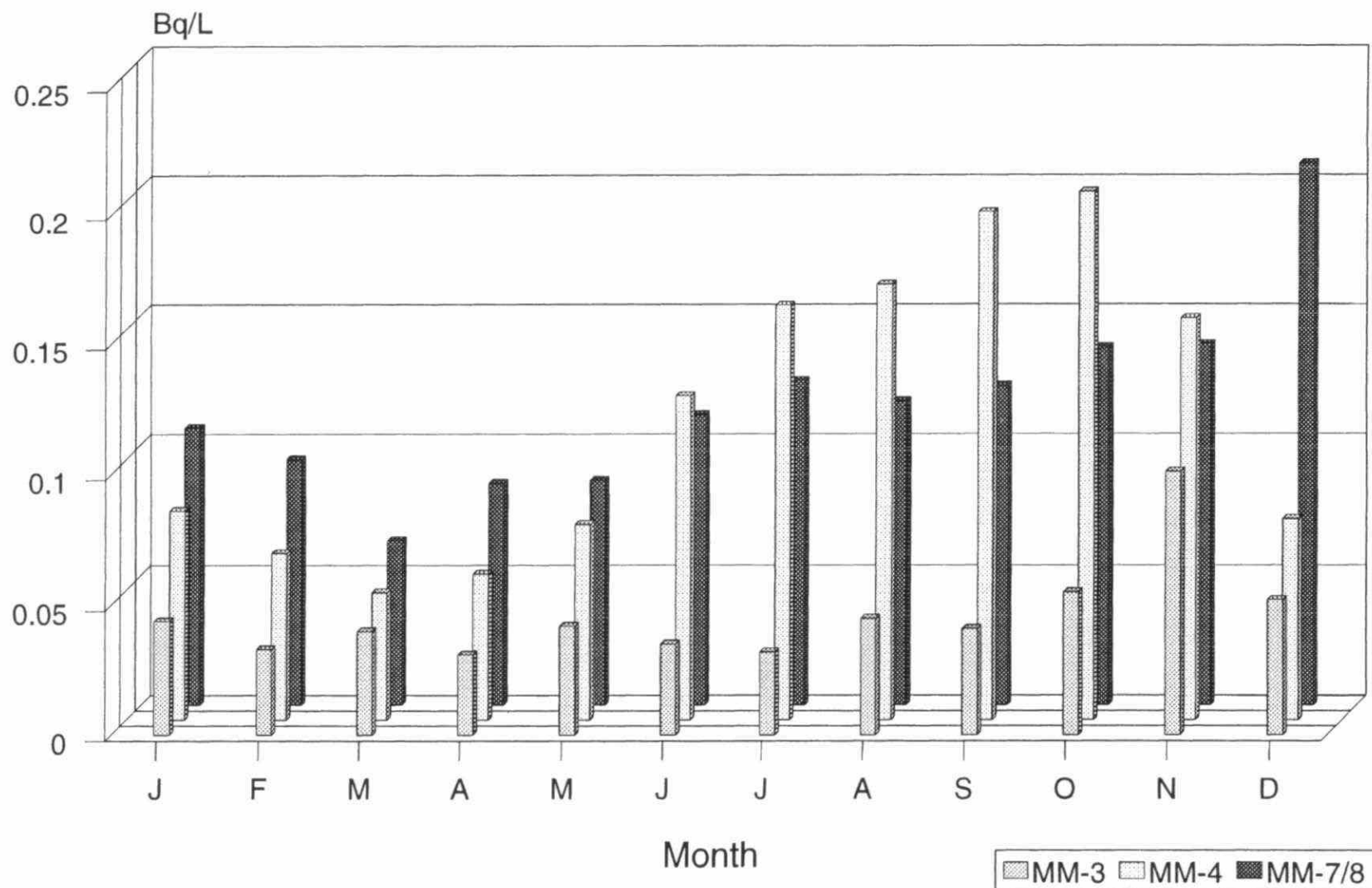
Figure 19a: Mean Monthly Distribution of Iron at PWQMN Sites. 1970-1999 - Madawaska Mine
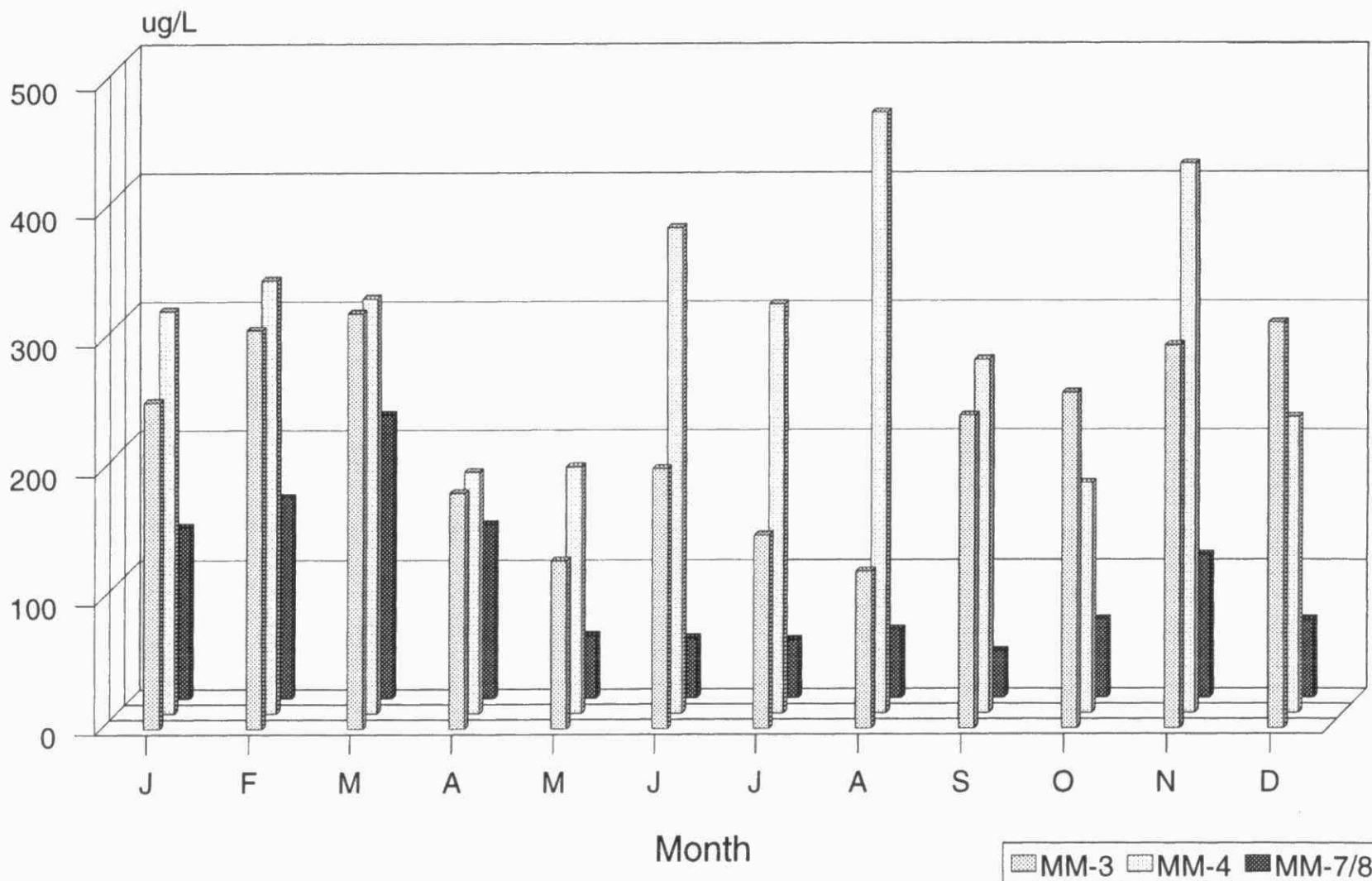
Figure 19b: Mean Monthly Distribution of Iron at PWQMN Sites. 1970-1999 - Bicroft Mine
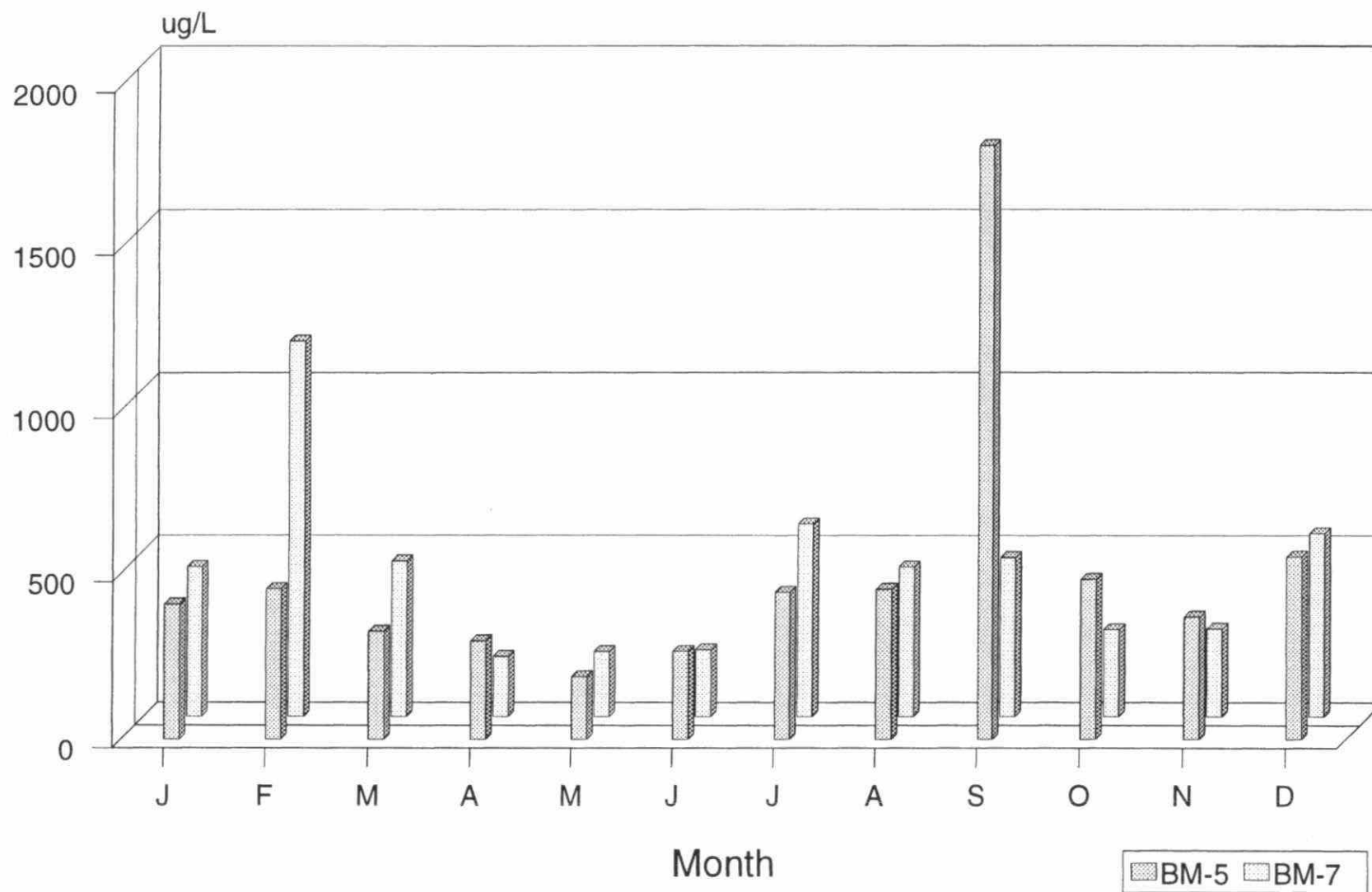
Figure 20: Mean MonthlyDistribution of Strontium at PWQMN Sites. 1970-1999 - Madawaska Mine
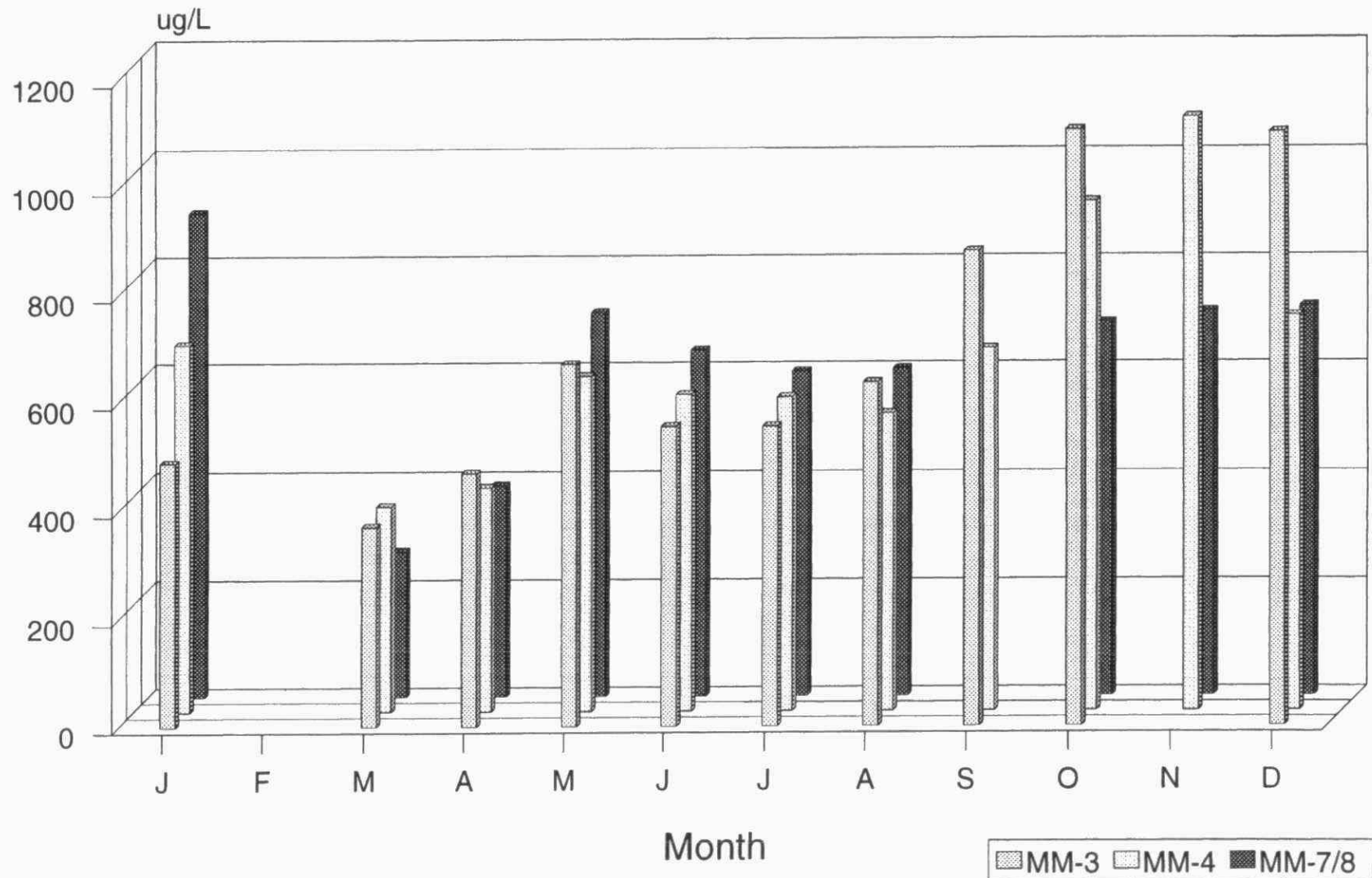
Figure 21: Distribution of Uranium in Sediments
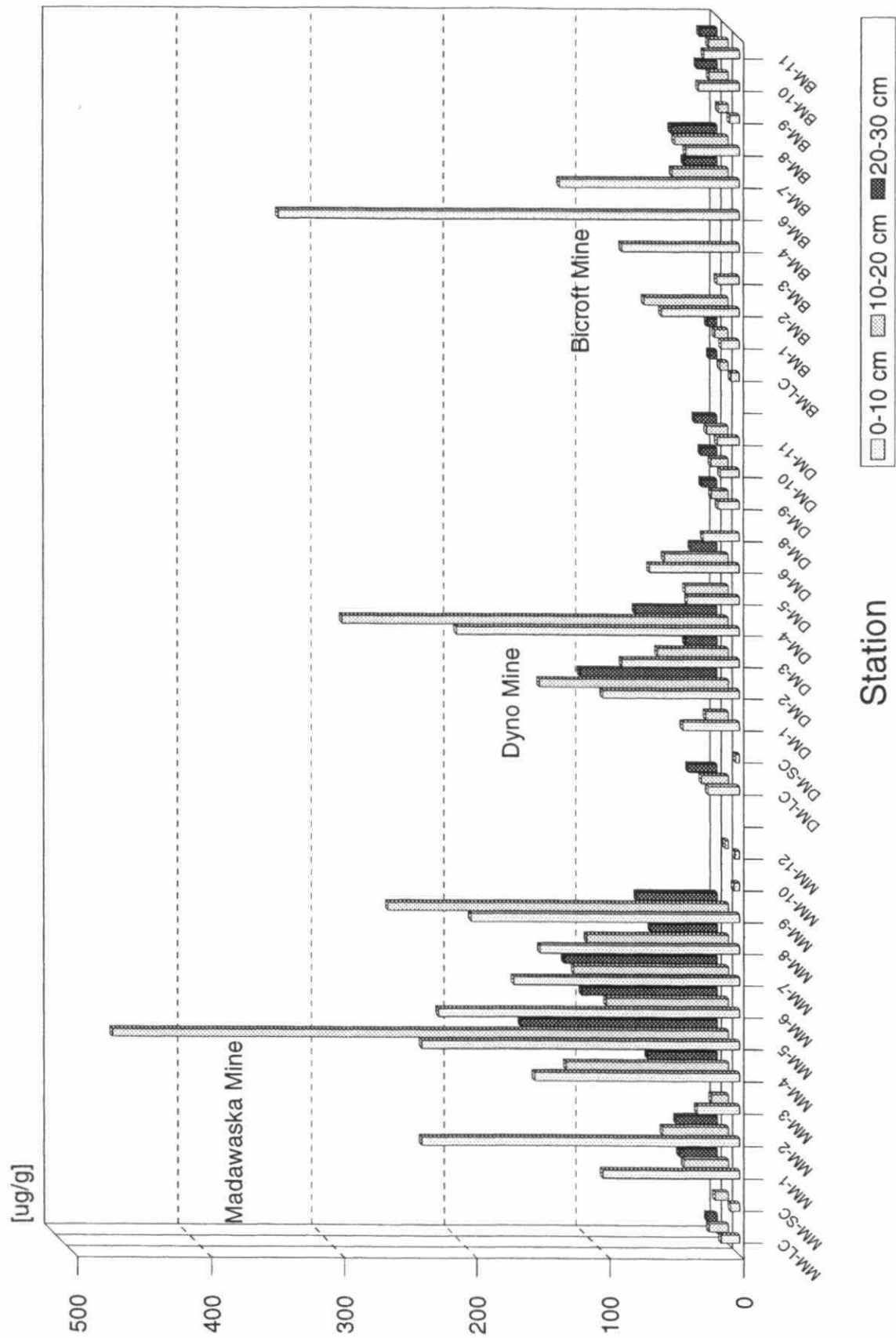
Figure 22: Distribution of Manganese in Sediments
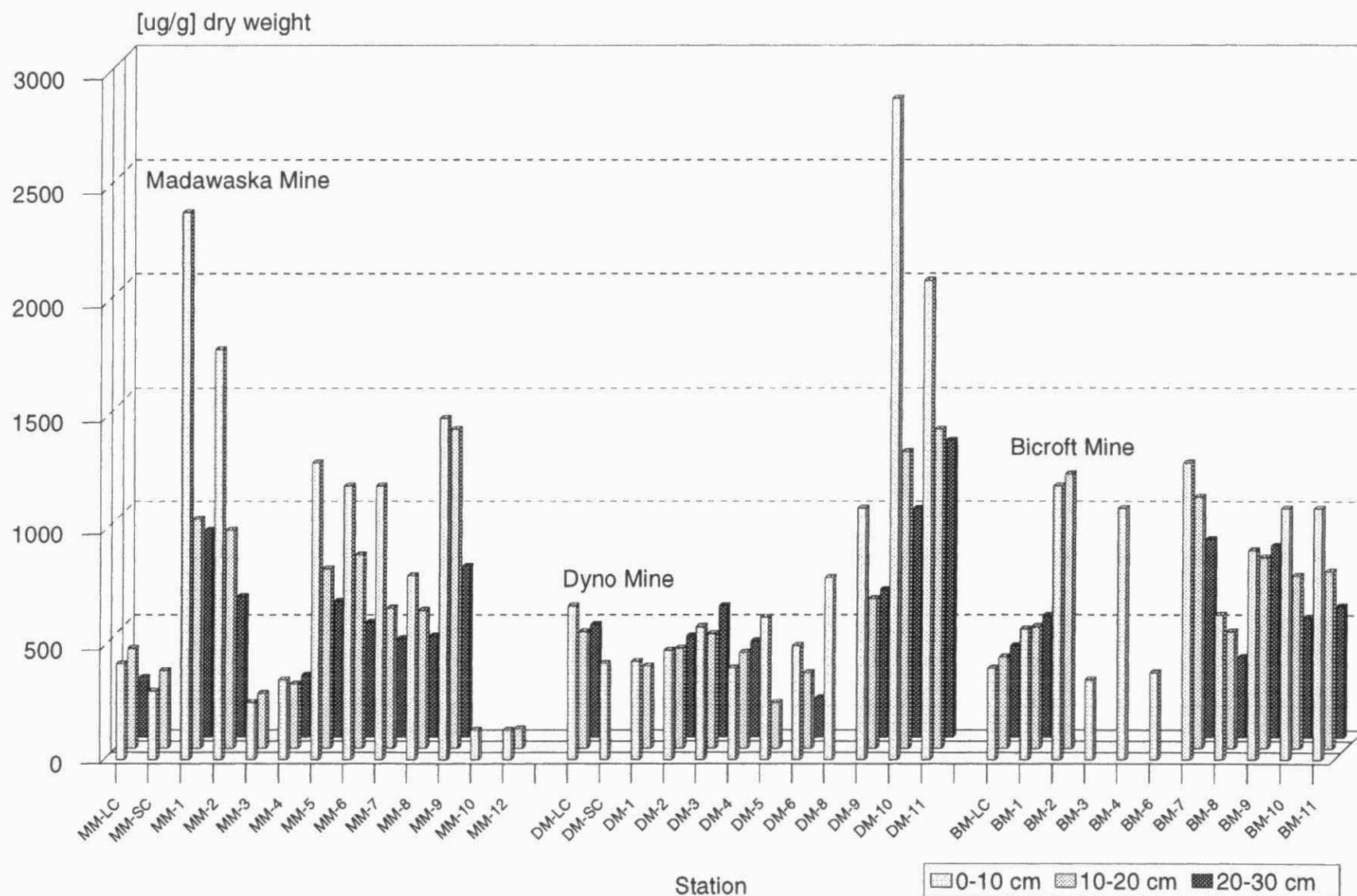
Figure 23: Distribution of Iron in Sediments
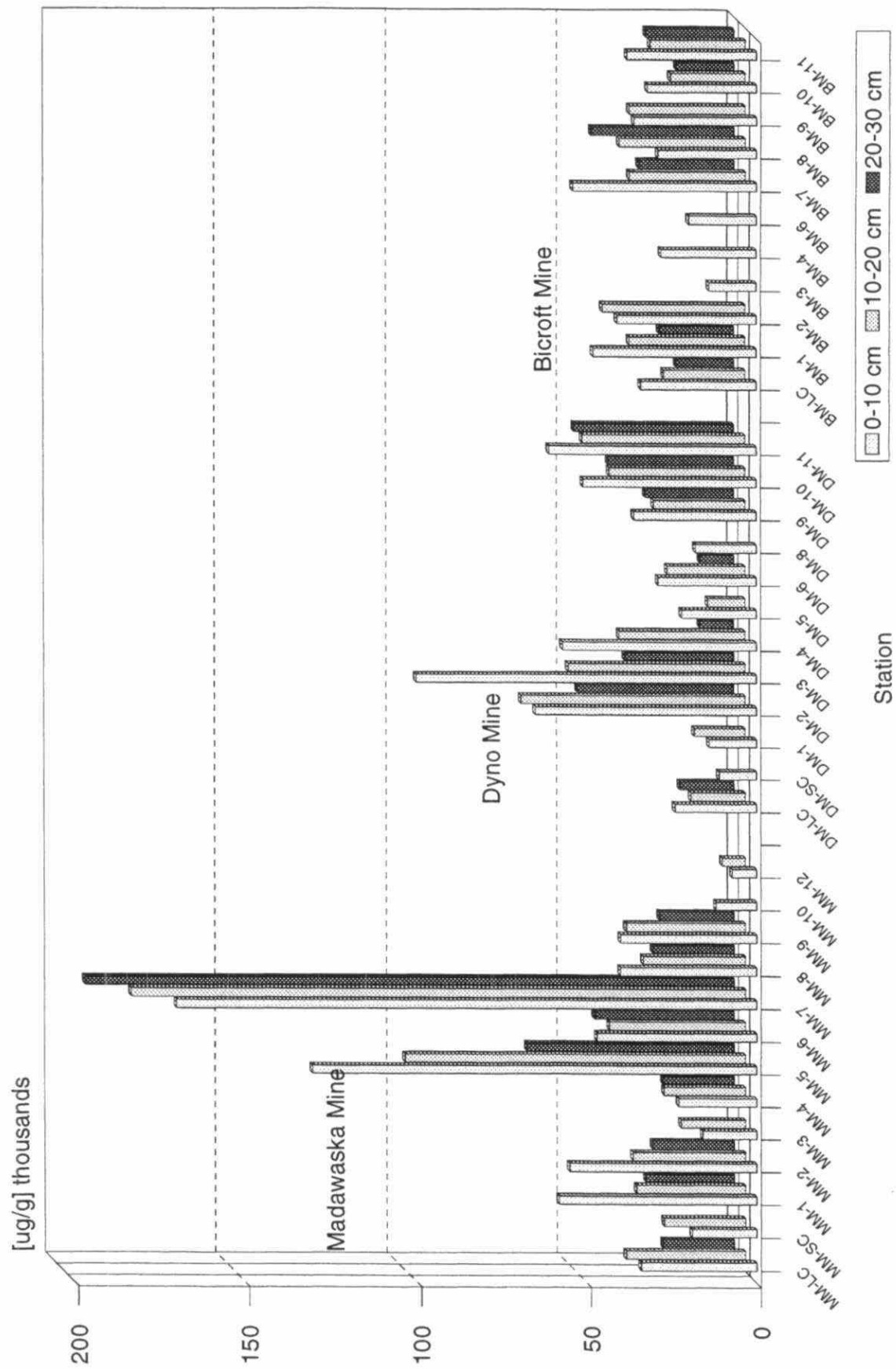
Figure 24: Distribution of Strontium in Sediments

Figure 25: Distribution of Radium 226 in Sediment
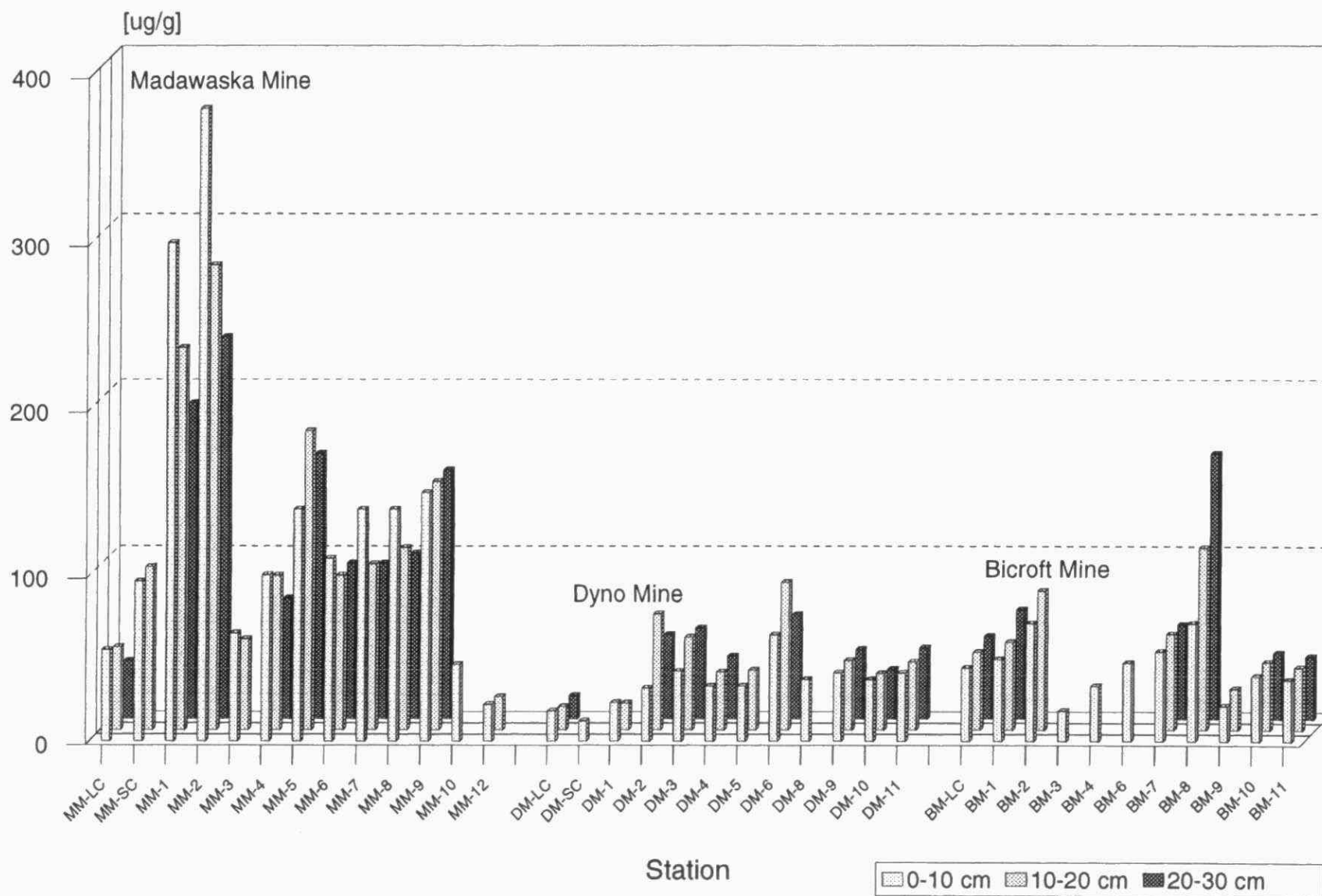
Figure 25: Distribution of Radium 226 in Sediment
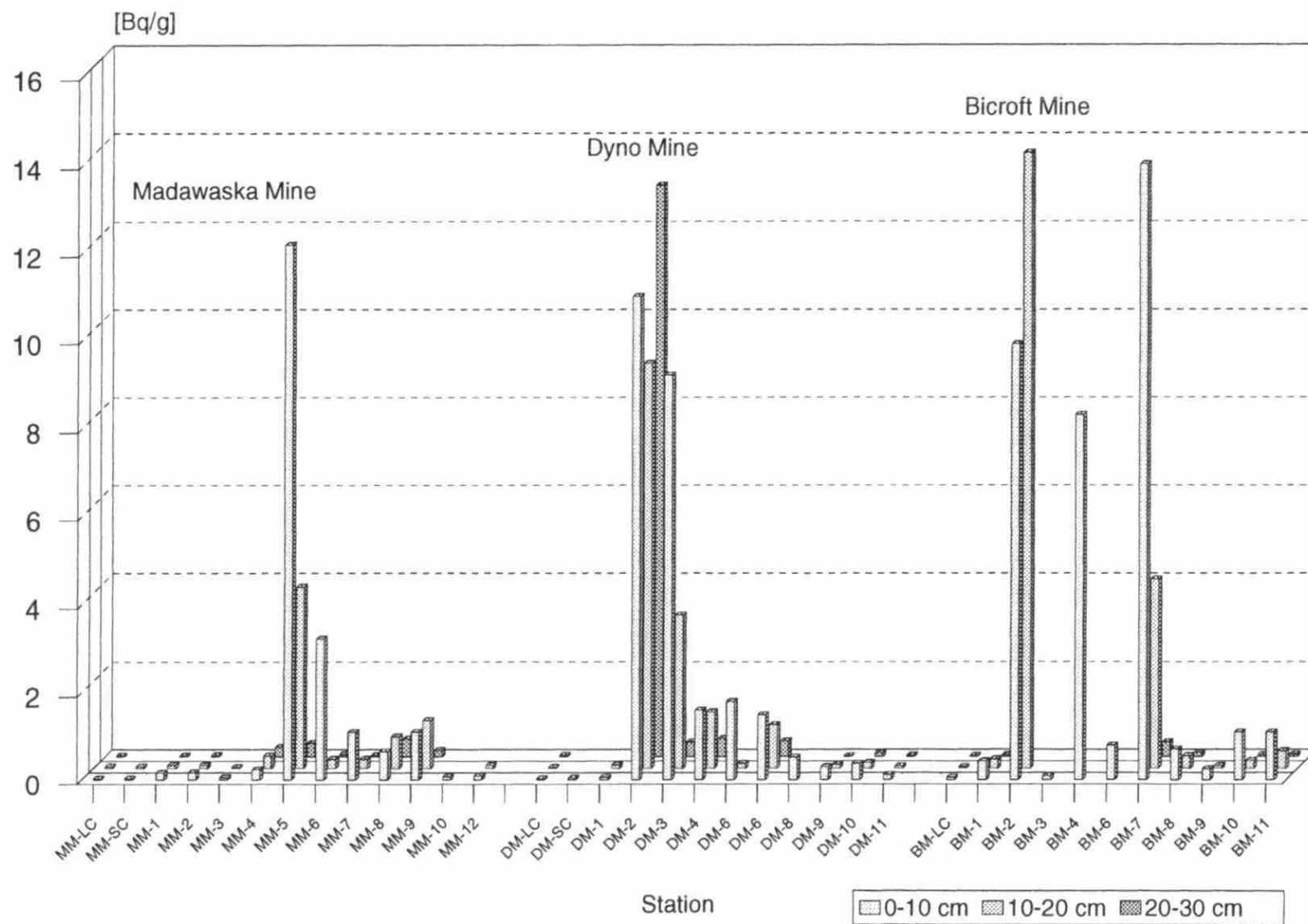
Figure 26: Distribution of Uranium 238 in Sediment
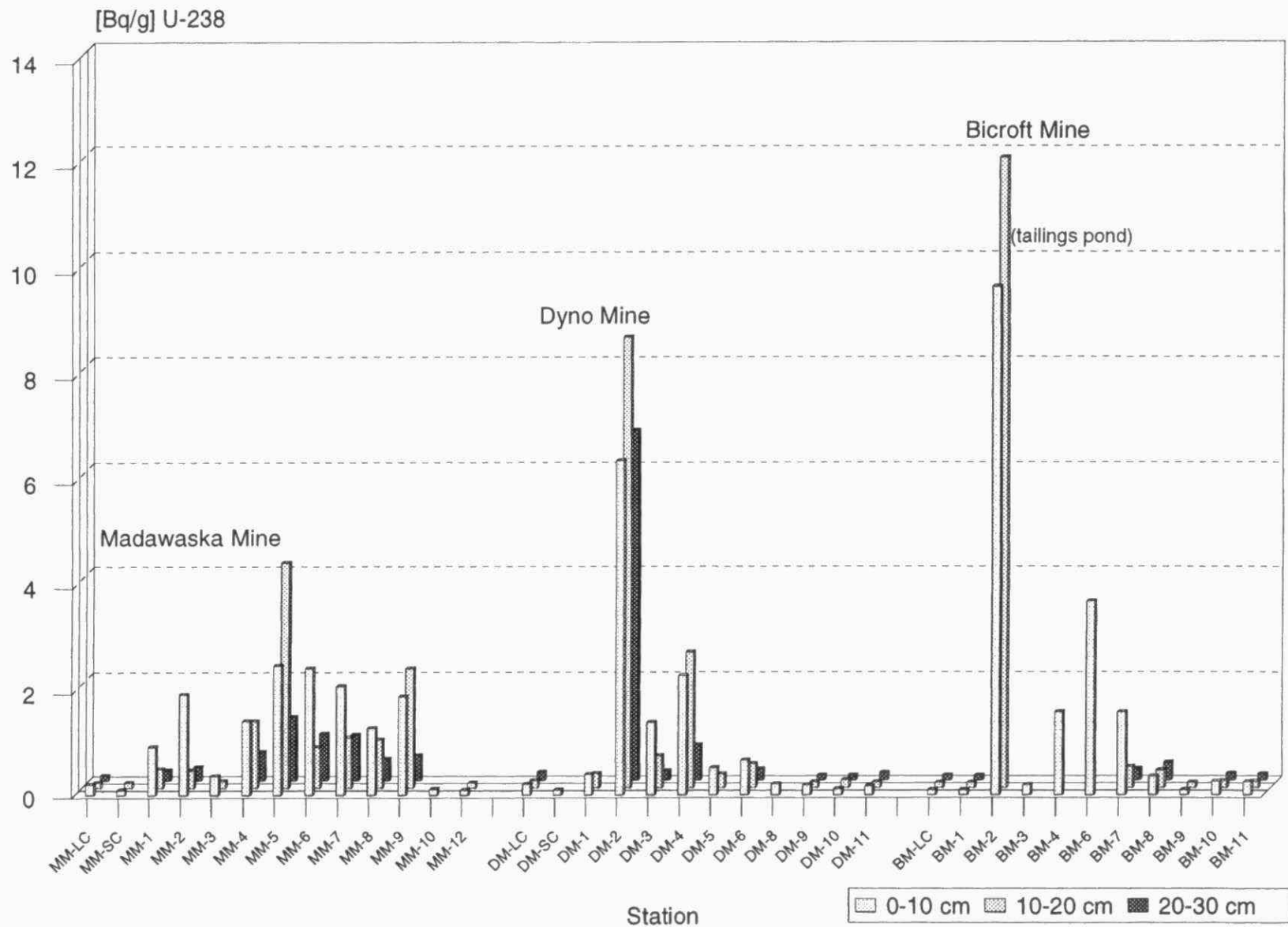
Figure 27: Summary of Bioassay Test Results - Mortality
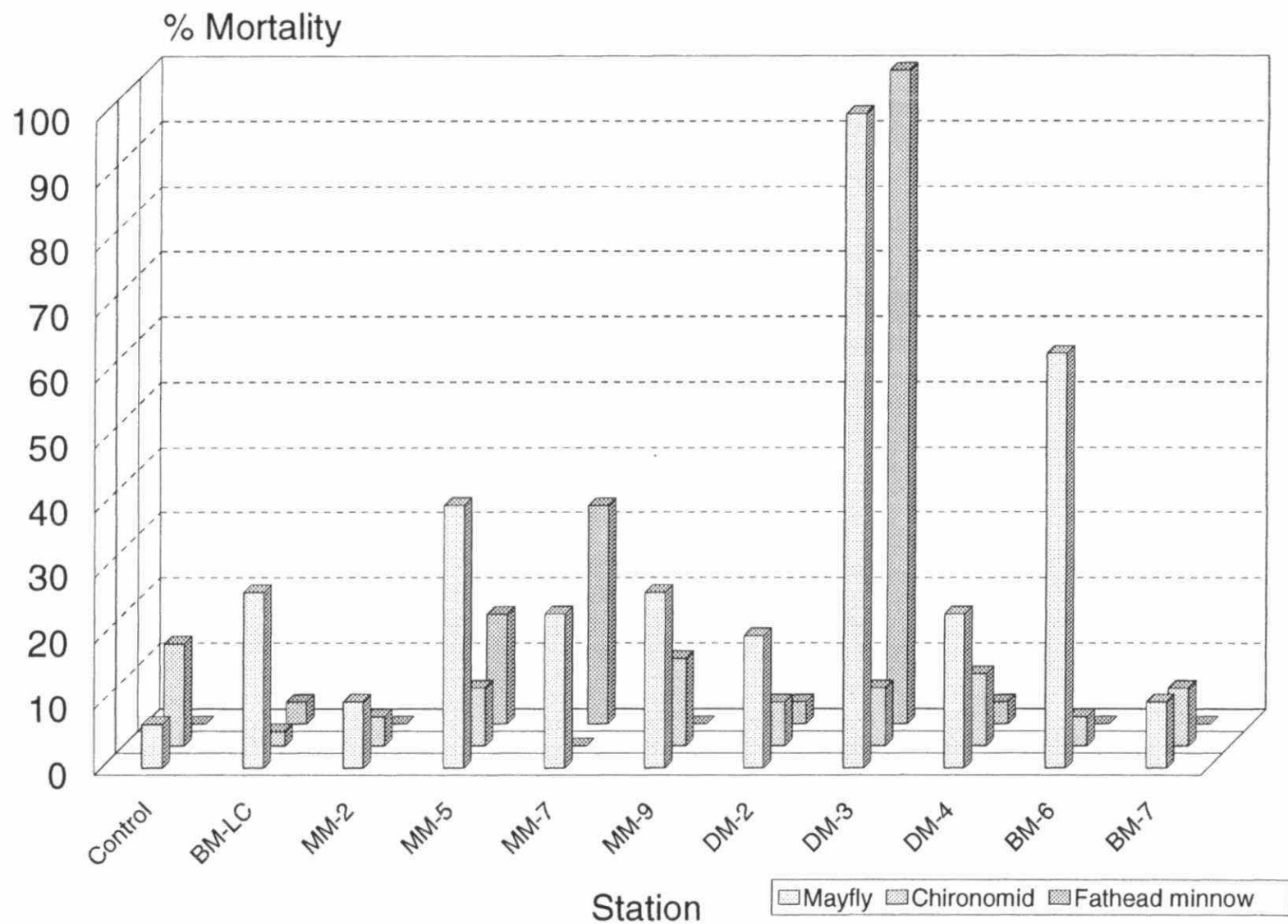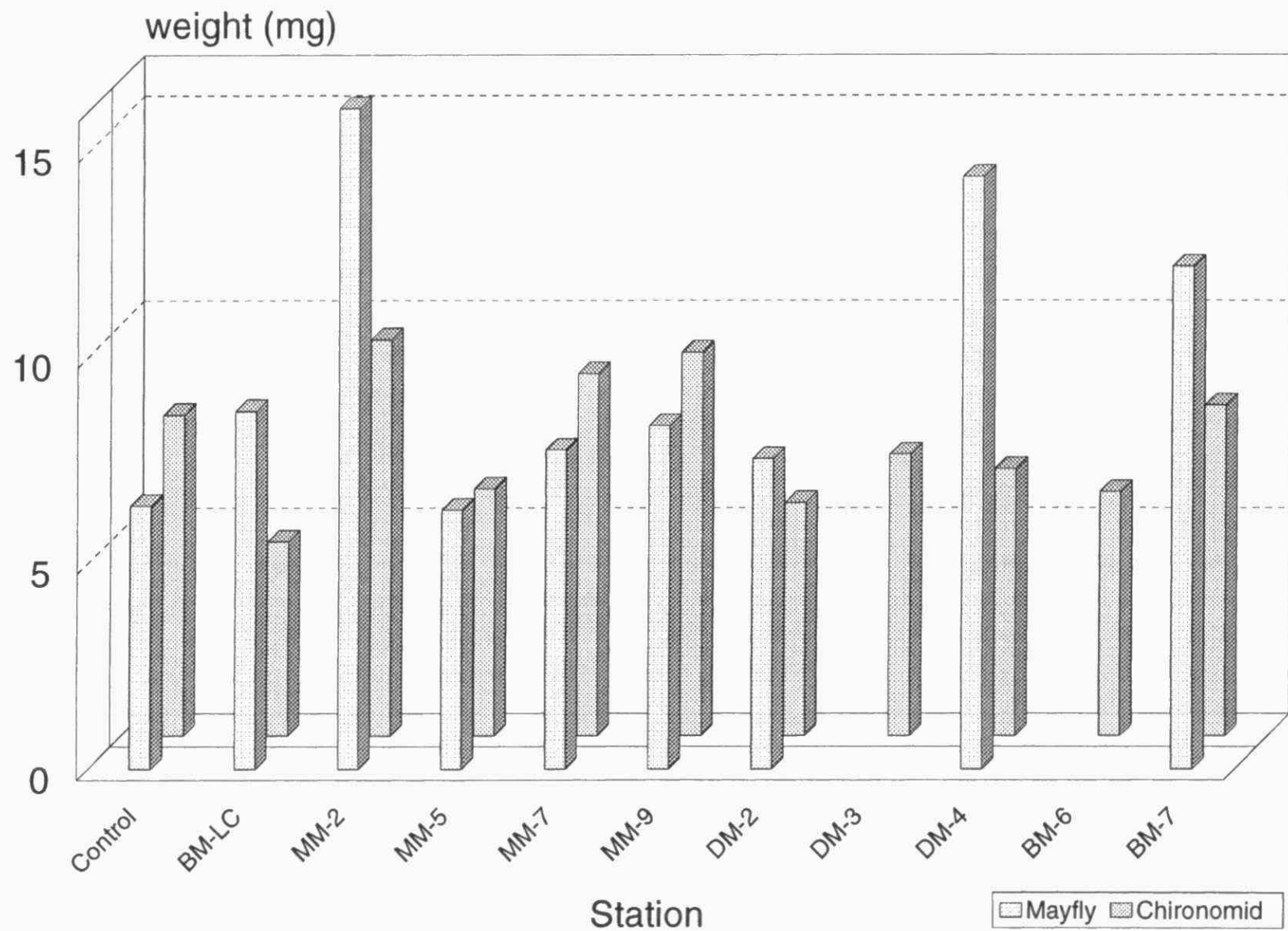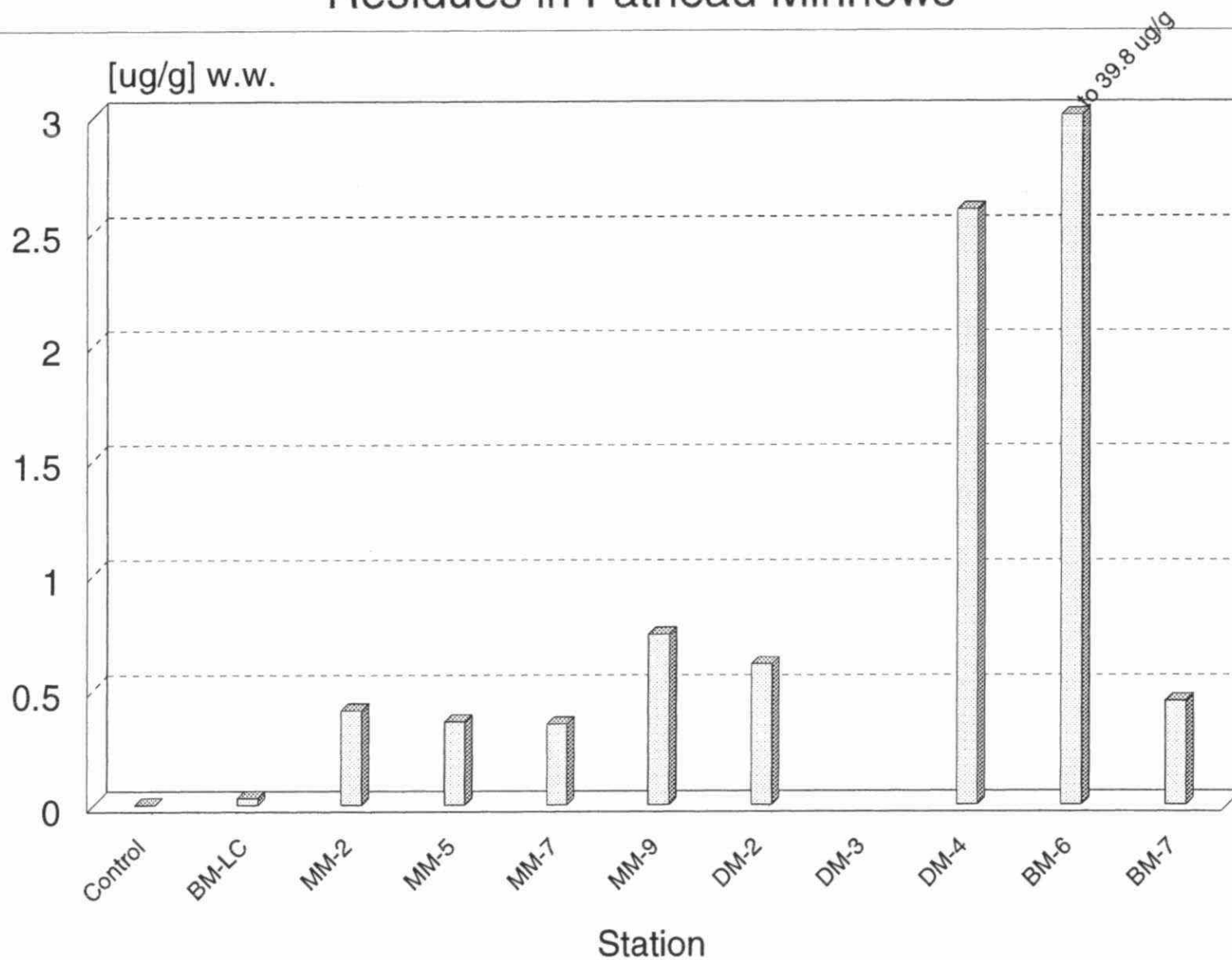
Figure 28: Summary of Bioassay Test Results - Growth

Figure 29: Summary of Bioassay Test Results - Uranium Tissue Residues in Fathead Minnows